I[st] INTERNATIONAL TECHNICAL TEXTILES CONGRESS

11-12 October 2002
İZMİR

Editors:
Assoc. Prof. Dr. Sevil YEŞİLPINAR
Asst. Prof. Dr. Merih SARIIŞIK
Res. Asst. Gülseren KARABAY

Dokuz Eylül University
Engineering Faculty
Textile Engineering Department

Dokuz Eylül University
Textile, Apparel and Dye
Research Center

IST INTERNATIONAL TECHNICAL TEXTILES CONGRESS

11-12 October 2002
İZMİR

Editors:
Assoc. Prof. Dr. Sevil YEŞİLPINAR
Asst. Prof. Dr. Merih ÖNEŞ SARIIŞIK
Res. Asst. Gülseren KARABAY

Dokuz Eylül University
Engineering Faculty
Textile Engineering Department

Dokuz Eylül University
Textile, Apperal and Dye
Research Center

I[st] International Technical Textiles Congress
11-12 October 2002, İzmir, Turkey

ISBN 975-441-195-6

Publisher: Printing Office of Dokuz Eylül University Presidency (0-232-463 43 50)

This book was published by the help of DuPontSA™

ORGANIZING BODIES

- Dokuz Eylül University Textile Engineering Department
- Dokuz Eylül University Textile, Apparel And Dye Research Center

ORGANIZING AND EXECUTIVE COMMITTEE

Prof. Dr. Mustafa Nazmi ERCAN

Prof. Dr. Yalçın BOZKURT

Prof. Dr. Gülseren KURUMER

Assoc. Prof. Dr. Fatma ÇEKEN

Assoc. Prof. Dr. Sevil YEŞİLPINAR

Assist. Prof. Dr. Merih ÖNEŞ SARIIŞIK

Res.Ass. Hakan ÖZDEMİR

Res.Ass. Halis ERDOĞAN

Res.Ass. Gülseren KARABAY

ADVISORY BOARD

SPONSORS OF THE CONGRESS

- SANKO HOLDİNG
- TÜRK TEKSTİL VAKFI
- AEGEAN EXPORTERS UNION
- ABALIOĞLU TEKSTIL SAN. A.Ş.
- ATAÇ A.Ş. ANTEKS WEAVING FACTORY
- COGNIS KİMYA A.Ş.
- ISTANBUL READY MADE AND APPAREL EXPORTERS UNION (İTKİB)
- KORDSA A.Ş.
- KORTEKS MENSUCAT SAN. VE TİC. A.Ş.
- ROTTA SAN.VE TİC. A.Ş.
- TÜBİTAK
- ASF SÖNMEZ PAMUKLU SANAYİ A.Ş.
- DUPONTSA A.Ş.
- POLAR SOĞUK İKLİM SAN.VE TİC. A.Ş.
- GEMSAN GENEL END.MAD. SAN.VE TİC.A.Ş.
- AUNDE TEKNİK TEKSTİL SAN. VE TİC. A.Ş.
- ALOHA TEKSTİL SAN. LTD. ŞTİ.
- DENİZLİ BASMA VE BOYA SAN. A.Ş.
- İNELLİ PLASTİK SAN.VE TİC. LTD.ŞTİ.
- TURKISH READY MADE PRODUCERS ASSOCIATION
- ÜNİTEKS TEKSTİL SAN.TİC.LTD.ŞTİ.
- YALAZ TEKSTİL SAN. VE TİC.LTD.ŞTİ.
- DEĞİRMENCİ GROUP
- DOĞUŞ TEKSTİL İŞLETMELERİ SAN. VE TİC. A.Ş.
- ETKİ KALİTE KONTROL VE TEST CİH. LTD. ŞTİ.
- DUPONT PRODUCTS S.A.
- ASTEKS KAUÇUK VE PLASTİK SAN. VE TİC. A.Ş.
- BENAR KİMYA SAN. VE TİC. A.Ş.

* Comfirmed companies when submitted to press.

CONSULTANTS OF TRANSLATIONS

Prof. Dr. Güngör **BAŞER**

Prof. Dr. Arif **KURBAK**

TRANSLATORS

Res. Asst. Vildan **SÜLAR**

Res. Asst. Hakan **ÖZDEMİR**

Res. Asst. Özlem **KAYACAN**

Res. Asst. Ozan **KAYACAN**

Res. Asst. Ü. Halis **ERDOĞAN**

Res. Asst. Gökhan **ERKAN**

Res. Asst. Banu **ÖZGEN**

Res. Asst. Musa **KILIÇ**

Res. Asst. Gülseren **KARABAY**

PREFACE

Human beings continue their studies in the present time, for further comfortable life as in the past. By these works, they both develop the existing products and tools and also invent brand-new products and tools. In the field of technical textiles, there are important developments especially in industrialized countries. The spread of these developments to all over the world is beneficial for all countries.

Dokuz Eylül University Textile Engineering Department and Textile, Apparel and Dye Research Center have organised Technical Textiles Congress at international level the first of its kind, in Turkey to gather researchers, industrialists and educators who work on this subject, and to discuss its technological and economical aspects.

In this book, there are 20 of oral presentations that are presented at "1st International Technical Textiles Congress" and 10 poster presentations.

We thank the devoted industrialists especially in Istanbul, Gaziantep, Bursa, Denizli, Çorlu, Antalya and İzmir for their contributions to The Congress, the contributors of papers and participants and wish that The Congress will be useful for all participants and textile industrialists.

Congress Executive Committee
October 2002

INDEX

PRESENTATIONS

TURKEY : CANDIDATE FOR LEADERSHIP IN SYNTHETIC YARN INDUSTRY

M. Taşdelen
Rayon and Synthetic Yarn Producers Association (SUSEB)
Secretary General, Bursa

ABSTRACT

Turkish Economy got acquainted with synthetic yarn industry by starting production of rayon fibre at Gemlik in 1938. For the last 64 years, the industry has been developing continuously and has been a close follower of new products developed by the synthetic yarn technology, such as polyamide, polyester and acrylic fibers. Today, the capacity of synthetic yarn production in Turkey, has reached to a capacity 120% of which is the country's need, that is one million tons.

This rapid growth in synthetic yarn industry and increase in product variety were supported by the importation regime which has been applied in between 1960 and 1989 and by Textile and Apparel Industry which has been developing hugely until 1980. In the last 20 years, there has been an increase up to 70% in both yarn and textile sectors' capacities. Although yarn production in Turkey was sufficient for these capacities, there was a increase in yarn importation between 1989 and 1999, because of reduced price of producers at the Far East. Starting in 2000, government put anti-damping law into validity to take precaution against unjust competition and to devaluate the Turkish lira.

Today, the synthetic yarn industry in Turkey, is one of the powerful, rapidly growing and wholly integrated textile and apparel industries of modern world. Investments which are appropriate for today, product integration and circulation of industrial products in European Community without cutom's duty made the synthetic yarn industry powerful. Owing to the high quality products, perfect services after sale and highly educated and experienced staff, the industry has been attained today's standards. Business philosophy of industry, in 64 years progress, is continuously varying from production to market orientation, from product volume to product value, from standard production to fantastic market, from classical products to developed products. As a result, Turkey will be a leading respectful synthetic yarn producer and provider of modern world.

THE OUTLOOK AND FUTURE PERSPECTIVES OF TECHNICAL TEXTILES AND MAN-MADE FIBRES

D. Morris
Comite International de la Rayonne et des fibres Syntetiques(CIRFS), Brussels-Belgium

ABSTRACT
Technical textile fibres are considered by many man-made fibre producers as representing a main growth area. The technical fibres sector, in order to maintain competitiveness is continuing to restructure, invest and innovate. The presentation defines technical textiles in the sector, provides information on the trends in the fibre consumption in technical textiles in Europe as well as giving data on the relative importance of technical products and where future growth areas may lie.

1. INTRODUCTION

Man-made fibres account for almost two thirds of the fibres used worldwide, and almost three quarters of the fibres used in Europe, taking all end-uses together. Within man-made fibres, technical fibres have a very special role. During the industry's development stage, technical fibres was cursory to the development of textile end-uses. Since the latter decades of the last century, technical fibres have developed, particularly in industrial economies, as the most rapidly growing portion of the fibres industry.

Technical fibres are defined by CIRFS as covering the following types of product, namely: high tenacity yarns of polyester, polyamide and viscose; speciality yarns and fibres such as aramid and polyamide; polypropylene yarns, excluding those used in floor coverings; and staple fibres for uses outside the traditional spinning technologies for example nonwovens.

2. MARKET DEVELOPMENTS

At a the beginning of the decade technical textiles consumed in Western Europe amounted to some 1.2milion tons, or about 22.5% of total fibre consumption. In the case of Turkey the figure was about 100,000 tons or just over 10%. For Western Europe man-made fibres accounted for some 85% of the total of which polyester both staple and filament totalled 413,000 tons, polypropylene 221,000 tons, cellulosics both staple and filament 241,000 tons and polyamide staple and filament 107,000 tons. For all man-made fibres the trend over time has been upwards until 2001 when the economic down turn in activity together with a lack of confidence adversely affected fibre consumption in technical textiles. The main technical end uses are given in Table 1, and by fibre in Table 2.

Table 1: Fibre Consumption in the Main Technical End Uses in Western Europe, 1995 and 2000.

000 tons	1995	2000
Tyres	91	93
Mechanical Rubber Goods	57	45
Other Woven Fabrics	217	265
Narrow Fabrics	13	16
Warp, Raschel and Leaver Knitting	21	26
Other Knitting	37	52
Sewing Thread	41	20
Ropes, Twines and Nets	53	77
Other Processes	6	12
Unspun	501	597
Total	**1,037**	**1,203**

Source: CIRFS

2.1 Tyres

Regarding tyres, high tenacity yarns of viscose, polyamide or polyester are firstly plyed and twisted to produce a cord. The cord is then woven using as weft yarn a very fine filling yarn resulting in a loose fabric. In Western Europe, viscose high tenacity yarn is ranked first in terms of mill consumption for tyres followed closely by polyester high tenacity and polyamide high tenacity yarn. In the rest of the world, polyester high tenacity yarns are by far the most important followed by polyamide high tenacity yarns. Viscose high tenacity yarns are rarely used. For very special types of tyres para-aramid is used. Air jet and projectile looms are used in the manufacture of tyre fabric.

2.6 Automobile Fabrics

Although classified by CIRFS as other furnishing fabric, some consider the automobile sector within technical textiles. Polyester filament yarn is without doubt the most used fibre in the automobile sector accounting globally for 95% of the total fabric used in automotive interiors, 50% of which is woven with an equal split between warp and weft weaving. The main growth area is Jacquard woven flat yarn. Details of the main fabric companies, subsidiaries and carmakers, together with production routes in Western Europe is given as an example in Table 3. Because of the requisite safety standards imposed upon automobile manufacturers most of the fabric used is manufactured in Western Europe. This will be maintained.

2.7 Sewing Thread

As can be seen the market for sewing thread has fallen and now accounts for only 20,000 tons. A further decline is likely during the present decade.

2.8 Ropes, Twines and Nets

In contrast to sewing thread the market in Western Europe continues to grow reaching 77,000 tons at the beginning of this century. Polypropylene filament yarn has a market share of 34% and polyamide filament yarn a further 31%. Further growth is expected.

2.9 Unspun products

As can be seen, unspun products for technical end uses have shown significant growth and are approaching 600,000 tons each year. Non wovens which is defined as a manufactured sheet, web or batt of directionally oriented or randomly oriented fibres bonded by friction, cohesion or adhesion. Important non woven products include papermakers felt, coverstocks where annual consumption is about 120,000 tons made almost entirely of polypropylene, medical and sanitary uses including sheets, hand towels and non wovens for hospital gowns, coating substrates and a myriad of other industrial uses, some details of which are given in Table 4.

Table 4: Non-woven Technical Products

Filtration:	air filtration, tea and coffee bags
Cleaning Products:	industrial wiping cloth, dusters, chamois and shoe
cleaning	cloth
Shoe Lining:	linings for shoes, boots and slippers
Automobile:	headliners, door panels, boot liners, automobile
upholstery	fabric
Electric Applications:	battery separators, cable insulation, computer
applications	
Abresives:	scouring applications
Civil engineering:	geotextiles, canal lining, landscaping, roofing
fabrics, wall	protection
Agriculture:	protective mats, greenhouse shading,
windbreakers	

Source: CIRFS

However non wovens are but one component of unspun products. Other end uses include cotton wool which consumed 50,000 tons in 2000, and is a declining market and filling and wadding, for example, for car seats. In 2000 the total filling market, including apparel and household textiles amounted to 291,000 tons, a rise of 45% on the 1995 figure. Polyester accounted for 85% of the total.

3. RESTRUCTURING

As with the rest of the European man-made fibres industry, the technical fibres sector is going through a major process of restructuring, an essential means of reinforcing the competitive position of companies.

The process of the demerger of fibre operations from chemical companies is coming towards its close, with the chemical companies share of fibres output having shrunk dramatically over the last 10 years, from almost two thirds to less than 20%. Most of the remaining chemical-owned operations are regarded as core businesses, integrated into the raw material supply chain. There is no doubt that, despite the huge contribution of chemical companies in the past to the development of the European fibres sector, the demerger process has contributed greatly to the growth of entrepreneurial flair, rapid decision-making and cost reduction.

The process continues, and it is interesting to review the different approaches of some of the major companies. Acordis has raised the issue of whether the current structure of grouping polyester, polyamide and viscose high tenacity yarns under common ownership with textile fibres was the best option. Its Twaron aramid business has found a new home with Teijin, facilitating the large-scale capital expenditure programme which was necessary to remain in the market. The Cordenka viscose tyre and industrial yarn business has been put together with the textile viscose yarns and fibres, following the veto by the European Commission of its proposed merger with Lenzing. If the polyester and polyamide businesses change hands, separately or together, it may well be as part of wider process of industry rationalisation.

KoSa's European high tenacity polyester business is well-focussed. It remains to be seen if the recent move to full control of KoSa's worldwide operations by Koch (previously a 50% partner) will have an impact on the future strategic direction of this large business.

The Sabanci Group in Turkey clearly has both ambitions and financial resources to consolidate its position in technical fibres. It has recently acquired full ownership of the SaKoSa polyester high tenacity yarn company, previously a joint venture with KoSa, but its main involvement in technical yarns is in polyamide, through two joint ventures with DuPont, in Turkey and internationally. In addition, a third joint venture with DuPont, DuPontSA, is one of the largest European producers of polyester staple for fillings and nonwovens.

Honeywell, whose polyester high tenacity yarn plant in France is an important element in its global fibres business, is clearly re-evaluating all of its strategic options after the European Commission forced the withdrawal of the takeover by General Electric. Its entry into European production in the early 1990s, with an advanced greenfield unit, has given it a strong position in the region.

DuPont remains an important player in its own right in technical fibres in Europe, as well as through its joint ventures with Sabanci, with a strong concentration on finer industrial yarns: it is one of the European leaders in airbag yarns.
Rhodia has recently consolidated its technical fibres business into a single unit, under the name of Rhodia Technical Fibers, together with its carpet yarn and fibres operations. It brings a wide range of strong market positions under a single direction, including high tenacity polyester and polyamide, polyamide staple for nonwovens and flock.

Other major players in the technical fibres market include staple producers such as Montefibre and Wellman, with a growing concentration on nonwovens and fillings uses, and textile yarn producers such as Trevira, TWD and Unifi, which have been building strong positions in automotive uses.

4.NEW ENTRANTS

The market continues to attract new entrants. Sioen in Belgium, one of the leading technical textile producers, has integrated backwards into production of polyester yarn, while Brilén in Spain has expanded from polyester textile yarns into high tenacity. Radici of Italy has entered the area, by acquiring a small unit in Romania and, more recently, by taking over Poliseda in Spain, with its production of polyamide and polyester technical yarns.

5.INVESTMENT

Continued investment is a necessity to feed market growth, produce to the increasingly high quality standards demanded by customers and retain a competitive cost structure. Recent investments of note include the major extension and modernisation being carried out by Montefibre in polyester staple, largely for nonwovens uses, the new nonwovens viscose line installed by Lenzing and a large expansion by Acordis of its airbag yarn facility. In aramid, both Teijin Twaron and DuPont are spending heavily to meet the expanding market, while DSM is embarking on a major expansion of its high tenacity polyethylene yarn facility in the Netherlands. Additionally, every company spends consistently, on incremental modernisation and de-bottlenecking.

6.INNOVATION

Research development is significant in technical textiles. New products have been developed. Furthermore, improvements to product specifications, quality and performance are essential to maintain and improve competitiveness, against both other companies in Europe and those outside, which in many cases have the advantage of lower labour, infrastructure, material or energy costs. Innovation is thus a key element in the strategy of European technical fibres producers. Innovation expenditure for the fibres industry as a whole runs at about 2 5 % of sales, but some technical fibres producers spend more than twice this proportion.

Innovation can arise internally; by cooperation with raw material suppliers, customers or equipment producers; or by cooperative research with institutes. It can be incremental or new. Each is a valid approach, but an essential element common to all is an innovative culture inside the company. Every technical fibres company wishing to develop its business for the long term must have, or acquire, such a culture.

7.CONCLUSION

The growth rate of demand for technical fibres is closely related to trends in other branches of European manufacturing industry. Although some traditional end-uses for textiles incorporating technical fibres are in decline, either relatively or even in absolute terms, for example, heavy-duty conveyor belting for use in mines and heavy industry. This has however been more than compensated for by development of new applications such as airbags, increased usage of fibres and textiles in transport, the expansion in performance sportswear and the replacement of other materials by high specification textiles. Indeed Concorde once again is flying aided by the contribution of technical fibres notably aramid protection for the fuel tanks, and ultra-high strength reinforcement for the tyres. Technical textiles are a growing, priority market for European fibre producers. They are committed to investment and innovation to serve this market. Close cooperation between fibre producers, customers and end-users will bring benefits to all.

Table 3: European Automotive Woven Fabric Production

Fabric Corporation	Market Share (est.)	Fabric Production	Fabric Subsidiary	Audi	BMW	Chrysler	FIAT	Ford	Gen Motors	Honda	Mazda	Mercedes	Mitsubishi	Nissan	PSA	Renault	Rover	SAAB	Seat	Skoda	Suzuki	Toyota	Volvo	VW	Woven Flat	Woven Jacquard
Milliken	17%	GB	Achter UK					*	*	*				*			*					*			●	●
		Germany	Viktor Achter	*	*			*	*			*											*	*	●	●
		Spain	Autotex					*	*					*					*					*	●	
Aunde	6%	Germany	Aunde		*			*	*															*		
		Spain	Aunde						*										*						●	●
Bergstena	4%	Germany	Bergstena																					*	●	
		Portugal	Bergstena																					*	●	
		Scandinavia	Bergstena						*									*					*			
C&A	4%	GB	C&A	*		*			*	*				*			*					*		*	●	
Eybl	17%	Austria	Eybl	*	*				*			*						*	*		*			*	●	
		Spain	Texcar						*										*							●
		Germany	DHI	*	*				*			*								*				*	●	●
Dewitte	8%	Belgium	DeWitte					*	*		*				*	*						*	*		●	
		France	Delcon												*	*									●	
Treves	13%	France	Chamarat					*					*		*	*					*			*	●	●
			Trody							*				*	*											
Thiery	14%	France	Copthiery		*				*						*	*			*	*		*		*	●	
		Italy	Rossini												*	*										
Guilford	9%	GB	Guilford					*	*	*			*	*		*	*	*					*		●	●
		Spain	Tybor							*	*			*											●	
Kneitz		Germany	Kneitz	*											*	*								*	●	●
Mattes & Ammann		Germany	Mattes & Ammann									*														
Rasch		Germany	Rasch	*	*				*						*									*		
Schmitz		Germany	Schmitz	*	*				*			*								*				*	●	
Wever		Germany	Wever	*																				*	●	
Vigano		Italy	Vigano				*								*	*										
Fidivi		Italy	Fidivi				*		*															*	●	
Sitoui		Italy	Sitoui				*																		●	●

Source: CIRFS

Table 2: Fibre Consumption in the Main Technical End Uses in Western Europe by Fibre, 2000

'000 tons	Cellulosi Filament Yarn	Synthetic Filament Yarn Polyamid	Polyeste	Polypropylen	Cellulosi Spun Yarn	Synthetic Spun Yarn Polyamid	Polyeste	Acrylic	Polypropylen	Others	Cotton	Wool
Tyres	37	21	34	0	0	0	0	0	0	0	1	0
Mechanical Rubber Go	3	10	28	1	0	0	2	0	0	0	1	0
Other Woven Fabrics	1	30	121	16	4	1	11	4	11	1	64	1
Narrow Fabrics	0	3	7	3	0	0	0	0	0	0	3	0
Warp, Raschel and Leaver Knitting	0	0	21	0	0	0	3	0	2	0	0	0
Other Knitting	0	0	31	1	0	0	1	0	4	0	15	0
Sewing Thread	1	3	0	0	0	0	4	0	0	0	12	0
Ropes, Twins and Nets	1	24	15	25	0	0	0	0	0	1	10	0
Other Process	0	1	10	0	0	0	0	0	0	0	1	0
					Cellulosic Staple	Synthetic Staple Polyamide	Polyester	Acrylic	Polypropylene	Others		
Unspun	0	0	0	0	194	15	123	2	203	1	56	3

Source: CIRFS

TECHNICAL TEXTILES AND APPLICATION POSSIBILITIES

A. Cireli –Ö. Kayacan – Ü.H. Erdoğan
Dokuz Eylül University, Faculty of Engineering, Department of Textiles,İzmir

ABSTRACT

The estimated share of apparel is 38%, home textiles is 37% and technical textiles is 25% in global textile market. Technical textiles are the most dynamic and improving industry with their high-tech, high valuable products that are available for newly generated consumption.

In various fields such as space industry, agriculture, architecture, geology, medical, transportation, technical textiles are utilized. By developing new fibers with high performance properties technical textile products will be varied and their application areas will improve.

INTRODUCTION

Technical textiles have been developed rapidly in recent years and will have an important role in textile industry. As a result of this rapid development and widely usage in other industries (engineering fields), it becomes very important to define and classify technical textiles properly. Defining and classifying technical textiles have been performed by many researchers in different ways. Nowadays, discussions and uncertainness are also going on. We define technical textiles in general meaning as: "Textile materials and products manufactured primarily for their functional properties and technical performances rather than aesthetic or decorative characteristics." (7).For years, textile products, used in these fields have been called 'industrial textiles'. But this term has now become to have a rather more specific meaning, referring to those products used as part of industrial processes (conveyor belts, filters, backing fabrics to carpets, electrical and communication cable reinforcements, etc.) and the term of industrial textiles has now become a sub class of technical textiles. Other common terms, referred to technical textiles are "functional textiles", "performance textiles" and "high-tech textiles". Some people use these terms more often in their studies. (22)

Actually, technical textiles are around us such as cables in our houses, insulation materials, floor coverings, tires and medical materials etc. Table 1 shows the general application areas of technical textiles.

Table 1. General application areas of technical textiles

• Advertising industry • Agricultural industry • Automotive industry • Air and space industry • Chemistry and pharmacy industry • Construction industry • Computer and electrical industry	• Environmental protection • Food and fishing • Furniture and home textiles • Leather industry • Medical industry • Casual and sports wear • Military and fire fields	• Petroleum industry • Packaging industry • Paper industry • Plastic and rubber • Printing industry • Machine industry • Gardening

Owing to their widely usage it's also possible to examine technical textiles more extensively under the following topics;

1. Medical textiles
2. Geotextiles
3. Textiles in military and defense industry
4. Safety and protective clothing
5. Filtration textiles
6. Textiles in transportation
7. Textiles in building and architecture
8. Composites in textile construction
9. Functional and sportive textiles

1. MEDICAL TEXTILES

The usage of textile materials in medical fields starts with the effort of curing the injuries and illness. As the health problems become important in people's lives more complicated products are developed. Not only the protective products but also the products, which can save the people's lives are being tried to develop. In 1950's after the development of synthetic fibers and especially in 1960's with the generation of non-woven materials, medical textiles were developed rapidly. These developments resulted in growing application areas of medical textiles.

Textile materials are used as fiber, yarn, fabric and composites in medical applications.

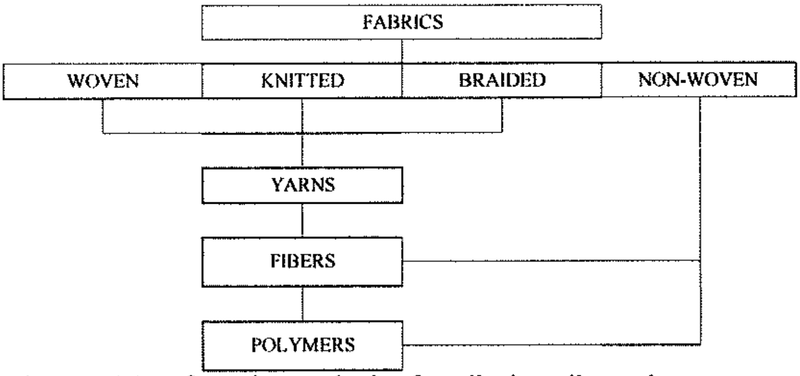


Figure 1. Manufacturing methods of medical textile products.

Non-woven products have a large application area from surgical covers to diapers, masks to shoes and caps. The main reason of this is easy of use, cost effectiveness, barrier characteristics and improving efficiency properties of the products. Because of the flexible characteristics of knitted products, appearance effects and handling properties, the application of warp and weft knitted fabrics have a wide application. Thus it is possible to produce from a basic finger bandage to hearth valves, vain prosthesis. Woven-based medical textiles are used for the products such as wound cares, bandages, plasters and surgical clothes. Table 2 shows the classification of medical textiles.

Table 2. Classification of medical textiles (2)

EXTERNAL APPLICATION		INTERNAL APPLICATION
Non-implantable Products	**Hygenic Products**	**Implantable Products**
- Wound cares	- Surgical clothes, masks, gowns, surgical hosiery	- Sutures
- Bandages	- Surgical covers	- Soft tissue implants
- Gauzes, lint,wadding	- Bedding	- Orthopedic implants
- Plasters	- Diaper/stock	- Cardiovascular implants
	- Clothes, wipes	
	- Protective clothing and uniforms	
Extracorporeal Devices		
-Artificial kidney	- Artificial lung	- Artificial liver

Table 3, 4, 5 and 6 show the fiber types and manufacture system of the products in Table 2.

Table 3. Non-implantable products (2)

Product Type	Fiber Type	Manufacturing System
Wound care		
-Wound contact layer	Silk, PA, CV, PE	Knitted, woven,nonwoven
-Absorbent pad	Co, CV	Nonwoven
-Base material	CV, Plastic film	Woven, nonwoven
Bandages	Co, CV, PA, Elastomer iplik, PP	Knitted, woven,nonwoven
Plasters	CV, Plastic film, Co, PP, PES, Glass fiber	Knitted, woven,nonwoven
Gauzes	Co, CV	Woven, nonwoven
Lints	Co	Woven
Wadding	CV, Cotton lints, wood pulp	Nonwoven

Textile materials are used in extra corporeal devices, such as artificial kidney (hemodialysis units), artificial liver and artificial lung (blood oxygenator) for blood purification.

Table 4. Materials in extra corporeal devices (2)

Product Application	Fiber Type
Artificial kidney	Hollow viscose, hollow PES
Artificial liver	Hollow viscose, carbon polyetherurethane
Artificial lung	Hollow PP, hollow silicone, silicone membrane, polysulphone

Table 5. Healthcare and Hygienic Textile Materials (2)

Product Type	Fiber Type	Manufacturing System
Surgical Clothing		
- Gowns	Co, PES, PP	Woven, nonwoven
- Caps	Carbon, CV	Nonwoven
- Masks	CV, PES, Glass	Nonwoven
- Surgical hosiery	PA, PES, Co, Elasthomer yarn	Knitted
Surgical covers		
- Drapes	PES, PE	Woven, nonwoven
- Clothes	PES, PE	Woven, nonwoven
Bedding		
- Blanket	PE, PES	Woven, nonwoven
- Quilt	Co, PES	Knitted, woven
- Sheet	Co	Knitted, woven,nonwoven
- Cushion	Co	Woven
- Pillow cases	Co	Woven
Incontinence diapers/stock		
- Coverstock	PP, PES	Nonwoven
- Absorbent layer	Superabsorbent, viscose, wood fluff	Nonwoven
- Outer layer	PE	Nonwoven

Tablo 6. Implantable medical textile products (2)

Product Type	Fiber Type	Manufacturing System
Sutures		
- Biodegradable	Collagen, polylactide, catgut, polydiokshanom, glicholydhomopolymer	Monofilament,multifilament
- Non-Biodegradable	PA, dacron, teflon, silk, linen, Co, PP and steel	Monofilament,multifilament
Soft tissue implants		
- Artificial tendon	PA, dacron,teflon,PE,silk	Woven, multifilament
- Artificial cartilage	Low density PE	
- Artificial skin	Chitin	Braided
- Eye contact lenses/ artificial cornea	Polymethylmethacrylat, silicone, collagen	Nonwoven
Orthopedic implants		
- Artificial joint/ bone	Silicone, polyasetat, PE	
Cardiovascular implants		
- Vascular grafts	PES, teflon	Woven, knitted
- Hearth valves	PES	Knitted, woven

2. GEOTEXTILES

The word Geotextile is the combination of geo- and textile, the prefix of geotextile, geo means earth and textile means fabrics. Geotextiles defined, as "A permeable geosynthetic comprised solely of textiles. Geotextiles are used with foundation, soil, rock, earth, or any other geotechnical engineering-related material as an integral part of a human-made project, structure or system" (1). In general geotextiles are permeable textile structures made of polymeric materials. They are used mainly in civil engineering application in conjunction with soil, rock or water.

The first application of geotextiles took place in the United States around the 1930's and it was reinforcement of road with cotton fabrics. The first commercial geotextiles, which also were known as filter fabrics, were industrial woven fabrics and were used for erosion control in the 1950's in the United States. Later, in 1960's, in Europe the first nonwoven geotextiles were produced with needle punching method. In accordance with the development of nonwoven production techniques and wide usage, the application areas and usage range of geotextiles increased. In fact, geotextiles are one of the members of the geosynthetic family. Geosynthetics include following members.

- Geotextiles
- Geogrids
- Geonets
- Geomembrans

- Geopipes
- Geocomposites
- Geosynthetic clay liners
- Geofoams

Geotextiles are the most widely used materials among this group and are real textile materials with respect to their structures.

Production of geotextiles, which was 1 million square meter in 1970' s, reached about 120 million m^2 in 1982, 250 million m^2 in 1985, 500 million m^2 in 1991 and 750 million m^2 in 2000. (6,23)

In the production of geotextiles polypropylene, PES (polyethyleneterephtalate), polyamide and polyethylene are widely used polymer-types as raw materials. Polypropylene and polyester are the most widely used two polymers in geotextiles. Polyamide (nylon) and polyethylene are used to a much lesser extent. These fibers are used in geotextiles as monofilament, multifilament, staple and slit film yarns. Generally, mostly used polymers are stabilized by UV and/or antioxidant.

Common weave types for geotextiles are plain, basket and twill weaves, plain weave is the most common and these are woven on wide industrial looms. Spun bonding nonwoven technique is widely used to produce geotextiles from polymers. Spun bonding process combines fiber spinning, web forming, web bonding and finishing in a continuous process. The knitted fabrics have few applications for geotextiles. Application ratios are as nonwovens 70-80 %, weavings 10-15% and others 5%.

The properties of geotextiles vary according to different properties of fiber and fabric (weave type, etc.), when used in production. Important mechanical properties of geotextiles are tensile strength, compressibility, seam strength, tear, burst, impact and puncture strength. Tensile strength is undoubtedly the most important among the mechanical properties of geotextiles, which directly depends on their type. Adequate tensile strength is necessary for all types of geotextile functions and installation. Wovens have the strongest tensile strength and the lowest elongation. In general, maximum tensile stress, elongation at break, toughness and modulus values are obtained through tensile tests.

The properties of geotextiles related to the surfaces with which they are in relation are also important. The friction coefficient between soil and geotextile material is also important. This mechanical interaction is characterized by the shear strength developed between soil and geotextile. A high contact shear strength is required when geotextiles are designed to move against each other. Fabric geometry greatly influences the shear strength parameters of a geotextile for a given soil type.

According to their application areas other important properties of geotextiles are hydraulic properties. These are porosity, permittivity and transmissivity. Porosity is the ratio of void volume of the geotextile to the total volume. This is important for geotextiles, which are used for the aim of filtration. Permittivity is also another

factor that influences the filtration properties of geotextiles and transmissivity depends on the types of geotextiles. The transmissivity of geotextile changes due to the cross section of the fabric. Needle-punched nonwovens, which are thicker than thermal-bended nonwovens and wovens, shall have a better transmissivity.
The durability of geotextile depends on stress, exerted by external media and raw material of geotextile (generally polymer). Abrasion is defined as the wearing away of any part of a material by rubbing against another surface. Geotextiles can be damaged by abrasion of large soil particles such as gravel or failure of soil.

The functions of geotextiles are;

- Seperation function
- Filtration function
- Water proofing function
- Reinforcement (stabilization) function
- Drainage function
- Protection function

3. MILITARY AND DEFENSE TEXTILES

" Of the last 3422 years, only 268 have been free of armed conflict somewhere in the world." These statistics show us the importance and continuity of military and defense industry. Textile industry is one of the two major industries (the other one is steel), which supports military field. The US Defense Department has in its inventory approximately 10.000 items made partially or entirely from textiles. Some 300 of these items are considered combat essentials (including uniforms, protective clothing, parachutes, sweaters, socks, gloves, sand bags, blankets and hospital supplies etc.) (2).
Considering the soldiers are exposed to environmental conditions more than civilians, the design, development and properties of military textiles must be organized with fastidiously.
Textiles in military can be classified in two categories. "Protective clothing" and "Textiles used in defense system".

3.1 Protective Clothing

Major requirements for military textiles are organized according to the conditions in war. For instance, while desiring durability for environmental conditions, physical properties such as heat stress and fatigue should be considered.

Military textiles with protective properties are classified as;

- Ballistic protective clothes (Vests and helmets)
- Chemical and biological protecting clothes
- Nuclear protection
- Environmental protection
- Surveillance, Camouflage

Ballistic protective clothes: Ballistic protection of a soldier involves protection of the body and eyes against projectiles with various shape, size and velocity. Main principle of ballistic protection is to dissipate the energy of the fragment and/or shrapnel through stretching and breaking the yarns in the many layers of the high performance woven fabrics in the ballistic vest. Each fabric layer reduces the energy of the projectile as a result of this. For maximum ballistic protection multi-layer woven fabrics, including maximum crossover points, are preferred.
Today the fibers, which are widely used for ballistic protection are Kevlar-Dupont, Twarion-Akzo, Technora-Teijin, [Spectra (ultra high molecular weighted PE)-Allied Signal, Dyneema-DSM-Hollanda, Tekmilon-Mitsui Petro Chemical-Japonya], Vectran(liquid crystal polymer based)-Hoescht Celanese) (4,20).
Chemical and biological protection: Chemical war started during World War I. To protect the soldier against chemical agents, permeable, semipermeable systems and impermeable barrier materials are used.
Activated carbon liners are used for permeable chemical protective fabrics. These kinds of fabrics provide evaporative cooling for heat dissipation and excellent chemical agent vapor protection. Permeable fabrics consist of a nylon based fabric with PUR foam, which is impregnated with activated charcoal.
Semipermeable materials consist of nonporous, ultraporous and microporous structures. Nonporous materials have good chemical/biological (CB) protection, but due to this construction they have low moisture/vapor transmission rate. The most desirable properties of microporous and ultraporous materials are high moisture/vapor transmission rate, high hydrostatic resistance and excellent CB protection.
Presently, a microporous semipermeable membrane in combination with activated carbon-containing foam is being used by the US Army. These are lightweight, thin and flexible fabrics. They prevent chemicals, which are in the form of liquid, gas and vapor without the need for adsorptive materials. These products also provide the protection against wind, rain, snow and other wet-weather conditions.
The impermeable barrier materials are made of rubber and coated fabrics. They serve as a physical barrier to chemicals including petroleum, oils and lubricants (POL). These fabrics offer the best CB agent protection. (8,9,14)
Nuclear protective fabrics: The purpose of military clothing is to provide high intensity thermal radiation and flame resistance. To protect against high intensity thermal radiation, absorption and transmittance values should be low and reflectance should be high. For this purpose, from 1940's to 1980's all nuclear protective fabrics were made of 100% cotton twill or sateen. Because of irregular surface characteristics, cotton has some disadvantages for nuclear protections, so

that nuclear protective fabrics are made of PES/Co, PA/PES and PA/Carbon blends. (9, 16)

Environmental protection: There are five basic climates; hot-wet, hot-dry, temperate, cold-wet and cold-dry. Military clothes are designed according to these climate types. In hot-dry, hot-wet and temperate environments 50% cotton, 49% nylon and 1% static dissipative fibers are used. The temperate uniforms are made from 7 ounce/yard^2 and desert military uniforms are made from 6 once/yard^2. In addition to this, in these uniforms camouflage is provided according to the desert and woodland conditions. In the same way, protection against cold is very important. There are systems, which show a good impact up to $-60°F$.

Polymer coating fabrics are used in protection against liquid water penetration. These are PVC, Neoprene, Acryl, PUR and rubber. Waterproof nylon fabrics coated with PUR offer moisture/vapor permeability up to 200 gr/m^2 per 24 hours. On the other hand for effective moisture/vapor permeable clothing a minimum of 2000-2500 gr/m^2 per 24-hour permeability is required.

Surveillance and camouflage: Traditional camouflage colors are black, brown and green. In snowy areas, white and lightweight clothes are preferred. Soldiers carry 18,5 kg loads in peace time, while 39-57 kg loads under combat conditions. So the weight of the clothes is an important factor.

3.2 Textiles Used In Defense System and Weapons

Tents, tactical shelters, rigid walls, gun covers, sleeping bags, boats, parachutes, life rats are some of the applications of the textiles in military field. Even fuel tanks in helicopters are made of textile materials.

4. SAFETY AND PROTECTIVE TEXTILES

Protective textiles are worn for preventing people from the risks or harmful matters and harsh environmental effects and/or decrease the effects of this media. These fabrics, which are known as industrial textiles, have to be durable to following effects.

- Extreme heat and fire
- Contamination
- Extreme cold
- Harmful chemicals and gases
- Radiation
- Bacteria
- Mechanical and electrical hazards
- Vacuum and pressure fluctuation

In 1996 200 millions m^2 fabric for high performance protective textiles was produced in West Europe. Moreover the consumption trend increases day by day. Nonwovens cover 60% of this amount. Properties of protective textiles vary according to their application area, which are summarized as follows.

Thermal protective textiles: They are designed against the effect of heat, flame, splash of melting materials, cold and radiation. (10)

Protective textiles for nuclear, biological and chemical hazards: Generally they are produced for military aims. In general, these are multi-layer structures, which are woven with synthetic or natural fibers and also reinforced with carbon fibers and foam.

Protective clothes for chemicals: There are four types of these clothes. (2) Type 1 offers highest protection against skin and respiratory exposure to chemical hazards. Type 2 offers prevention against only liquids, may not prevent the penetration of gases or vapors. Type 3 is the same as Type 2, but it offers little prevention to gases. Type 4 is the normal work clothing. It offers prevention against dirt and oils. In chemical protective clothes various raw materials as butyl/nylon, butyl, rubber, chlorinated PE, chlorinated ethylene propylene (Teflon), polycarbonate, coated polyethylene are used for production of various clothes, gloves etc. (14)

Protective clothes for mechanical hazards: They are used to protect from mechanical hazards as cut, tear, puncture, splash, impact and abrasion. Textiles for mechanical protection can be manufactured from high strength textile fibers, which offer the above properties. According to the USA statistics, each year more than 1 million workers suffer job related injuries. 25% of these injuries are to the hands and arms. So gloves have an important role in mechanical protection. Raw materials, which are used in mechanical and physical protective clothes, are para-aramids, high density PE (HDPE), nylon/Co blends and special fabrics produced with metallic yarns.

Protective clothes for electrical hazards: They are used to protect from two types of electrical hazards, classified as electromagnetic hazard and electrostatic hazard. People who work under the effect of high voltage must prefer flame resistant, durable and conductive protective comfort clothes. For this aim, fabrics, which are produced with natural, synthetic and metallic yarns are preferred. These clothes were introduced in 1970' s and are still in use today. There are fire retardant textile fibers and stainless steel fibers with diameter 8-12μm in these clothes. For example 25% stainless steel fiber / 75% wool or 25% stainless steel fiber / 75% aramid fiber mixtures are used. The human body may get electrostatically charged. The body transfers its charge to a metallic object upon contact, thus creating an electrostatic discharge. This discharge can damage an electronic part so this phenomenon is very critical for space suits. (11)

Clean room textiles: These clothes, which are called with this name, protect the environment from the wearer. The human body sheds one billion skin cells every day and the body and its clothing also carry a good amount of dust, ions, hair, textile lint, cosmetics, perfume and tobacco smoke. So it is obvious that the important role of this type of clothes, which prevents contamination, in optics, shape components, food, pharmaceuticals and automotive components cannot be denied. (2,5,8)

Protective clothes for radiation: Radiation protection is necessary for nuclear plant employees, x-ray professionals, workers in cancer treatment centers and other places subject to ionizing radiation. In these cases gloves and lightweight protective clothing may be enough for protection. However in case of gamma radiation energy will penetrate through the suits. In these cases, PES/Co, PA/PES blending clothes gain important role in nuclear protection.

High visibility textiles: These clothes can be classified as protective clothes also. There are three major types of these clothes.

I. Reflective materials: They shine when struck by light

II. Photo luminescent materials: They absorb daylight or artificial light, store energy and emit a green-yellow glow in dark.

III. Fluorescent materials: Red-orange is visible during the day.

According to American statistics, in night time vehicles strike and kill more than 4000 pedestrians and injure more than 30000 pedestrians annually in USA (2).

5. FILTRATION TEXTILES

Filtration can be defined as the separation of one material from another. The main purpose of filtration is to improve the purity of filtered material.

Filtration fabrics are used in vacuum cleaners, power stations, petro-chemical plants, sewage disposal, chemicals, cosmetics and also widely used in cigarette filters.

The dust collection efficiency of filtration fabrics can range from 25% to 99% depending on the fabric type and also filter lifetime before plugging is an important parameter for filtration. (19).

Table 7 shows comparison of filter characteristics of woven and non-woven fabrics, which are used for filtration

Table 7 Comparisons of filter characteristics of woven and non-woven fabrics.

Nonwoven	Woven
-Low cost manufacture	-Expensive manufacture
-3-Dimensional structure	-Largely 2-Dimensional structure
-Low strength with high deformation	-High strength with low deformation
-Bulky cross section	-Flat cross section
-Filter fineness restricted by fiber fineness	-Thread fineness restricts filter fineness
-In dept and surface filtration due to their construction and thickness	-Surface filtration
-Fibrous structure suitable for graduated filtration (coarse-medium-fine); layered web structure removes coarse and fine particles separately resulting in long running times	-Warp/weft structure can be produced in the form of "funnel" effect, thus easily causing penetration, preferential deposition and increased filter resistance
-High standard of separation with high air permeability and high surface loading through utilization of maximum fiber surface area.	
-Separation is performed by impact, obstruction or diffusion action or electrostatic charge	-Sieve action
-Pores may be greater than the particles to be retained (20-60μ), and yet produce very high efficiency of separation.	-Only those particles are retained which are larger than the spacing between the thread intersections.

The ratio of the volume of air or void contained in the fabric to the total fabric volume is defined as porosity. The amount and distribution of this air space influences many important fabric properties including the efficiency of filtration in industrial fabrics. Knowledge of the air permeability of fabric is particularly important for many purposes such as suitability for use as vacuum cleaner bags and filters.

In dry filtration, the separation of dust and other solid materials, gases is important. Application areas for dry filtration are filtration in automotive and building devices, filtration in the industrial and medical face masks, filtration in vacuum cleaners, filtration in mining, chemical, iron and steel industry. The most widely used fiber in dry filters for textile materials is polyester (approximately 79% of all materials). Other raw materials, which are used for dry filtration, are nylon, polypropylene, glass and sulfur (PPS) fiber. Nonwoven fabrics are most widely used in the filtration of gases.

Liquid filtration is the separation of solid material from liquid material. Polypropylene fibers are widely used in woven and nonwoven structures in liquid filtration to improve filtration properties, because of their resistance to chemical breakdown (approximately

50% ratio). Application areas of liquid filtration are filtration bags, pool filters, beverages sector, cosmetics and pharmacy, control and processing of petroleum derivates, chemicals, washing with liquids and textile dying.

6. TRANSPORTATION TEXTILES

Technical textiles are widely used in transportation vehicles including cars, trains, buses, airplanes and marine vehicles. Nowadays, in automotive industry, there are more than 25 major textile applications such as tires, filters, interior trims etc. also it is the same for marine and airplane industry. (2,3)

Approximately 12-14 kg of textile materials is used in an average car. 2/3 of textile application in automotive industry is performed for interior trim (roof, lining, seat covering, side panels and carpets), rest of it is used for tires, hoses, airbags, insulation and filters.

Tires: Textile applications also take place in tire industry. More than 800.000.000 tires are manufactured worldwide in each year. A tire consists of rubber, fabric, chemical and steel.

The major sections that contain textile materials are: *Filling fabric*: Placed in around the bead. It is a diagonal woven fabric coated with rubber. *Cord fabric*: It is the core structure of the tire. It is produced by using high tenacity filament nylon 6.6 , nylon 6, PES or viscose. Generally warp threads are made of these yarns while weft threads are made of cotton. Aramid, glass and steel are the other fiber types from which cord fabrics can be produced. *Chafer fabric*: It is used for the reinforcement of the tires. The fabric type differs according to the aim of usage. It provides abrasion resistance at the assembling point of the tire to the vehicle body. It is woven by using multifilament, monofilament and texturized yarns. (2, 15, 24)

Seat belts: They prevent the forward movement of the wearer. The seat belt should be able to carry a static load of around 3.300 lb (1500 kg) with a minimum extension of 25 to 30 %. They are narrow fabrics woven from filament yarns in 2/2 twill weave. The major reason for preferring this kind of weave is the parallel placement of warp yarns in front and back face of the fabric, so that high warp resistance and low elongation capacity is provided to the material. Also it is possible using hearing bone weaves in manufacturing seatbelt fabric. (2)

Airbags: They are manufactured by using nylon 6.6 , nylon 6 (less often) or PES. After weaving process, the fabrics are coated by neoprene rubber or silicone rubber. Nylon 6.6 , polyester or Kevlar fibers are used as sewing threads.

Other application fields: There are filters for various purposes such as for air, fuel, oil and water transportation and fuel purification. Textile materials and

especially non-woven structures are used. Moreover textile materials are used more often as covers for trucks that carry open cargoes.
Carpets, nonwovens and other fibrous materials are effective for sound deadening in cars. Seats, roof covers and floor carpets have a great effect for noise isolation inside the car. Inside roof lining can be made of two-layer polyester. Car seats, if covered with an air permeable fabric, can insulate the low frequency sounds. (12)
Technical textiles are also used as several types of conveyor belts. These belts serve as transportation roads for loose bulk material, such as pebble stones, sand, ores etc. Traditionally these belts are woven on projectile weaving machines with tucked in selvedges.

7. THE TEXTILES IN ARCHITECTURE AND CONSTRUCTION

Textile materials are used in buildings for years. The usage of these materials is increased with the development of polyester. Nowadays these materials (coated fabrics) are used in airports, stadiums, sport halls, exhibition and display halls and storage bases for industrial and military bases.
The advantages of fabric envelope can be 1/30th of the conventional envelope of bricks mortar or concrete or steel (2). Therefore, the cost is reduced and also less structural reinforcement is needed. Textile structures provide large obstruction-free spans, which can be used in exhibition and sport activities. They can be taken down and also re-erected easily. Some fabrics do not get damaged easily and can be repaired. They resist better to major destructive forces such as earthquake. Membrane structure can also be used in buildings. Membranes are divided in to three types as meshes, films and fabrics. Meshes are porous materials, which are produced from woven or knitted fabrics. Films are transparent polymers in sheet form. Membrane fabrics, which are coated or laminated with synthetic materials, improve the strength and environmental resistance.
The textile structures, which are used in construction of a building, are made of a base fabric and a layer, which covers the base fabric. Base fabrics are generally produced from synthetic fibers to provide the required strength. Coatings are made of plastic materials and synthetic rubber. They provide water proofing and protect the base fabric against the sunlight and the weather conditions.
Coating fabrics are usually more expensive than the laminated fabrics but their tensile strengths, abrasion and flex resistances are greater and they have longer life. Laminated fabrics are economic in general applications. Their tear resistances are good. But under repeated flexing, they may loose their lamination properties.

8. TEXTILE STRUCTURAL COMPOSITES

Composites can be defined as a combination of dissimilar materials to perform a task that neither of the constituent materials can perform alone. Generally speaking, a composite is made of two components: Reinforcement material and matrix (binder).
A textile structural composite is also made of a textile reinforcement structure and a matrix material. Textile reinforcement structures are generally flexible and can be made of fibers, yarns or fabrics (woven, braided, knitted, nonwoven). Matrix materials can be thermoplastic or thermoset polymers, ceramic or metal.
The functions of matrix material are to bind the fibrous materials together and protect them from outside effects. Matrices transport the forces and stresses acting on the boundary of the composite to the fibers. They also help to strengthen the composite structures.
The most commonly used fiber materials in textile reinforcement structures are fiberglass, carbon and aramid fibers, which are high modulus materials. Boron fibers are used in epoxy, aluminum or titanium matrices. Matrices bind fibrous materials together and hold them in particular positions and orientations giving the structural integrity. They serve to protect fibers from environmental effects and handling. Both thermoset and thermoplastic resins are used as matrices in textile structural composites.
Thermoset resins: The most widely used thermoset resins are polyester and epoxy resin. Thermoplastic resins: Thermoplastic materials can be classified as commodity thermoplastics and engineering thermoplastics. Commodity thermoplastics such as polyethylene, polypropylene, polyvinyl chloride and polystyrene exhibiting very little resistance to high temperatures. Examples of engineering thermoplastic resins, which have been considered for use in composites, are PEEK (polyether-ketone), PPS (polyphenylene sulphide) and PEI (polyetherimide) (2).
Textile reinforcements can be in various shapes and forms. Classification of them can be done in several ways depending on the preform structures' parameters. These classifications were performed by several scientists. In general, several variables of classification of textile structures were denoted as dimension, direction of reinforcement, fiber continuity (continuous-discontinuous), linearity of reinforcements (linear-nonlinear), bundle size in each direction, twist of fiber bundle, integration of structure (laminated or integrated), method of manufacturing (woven, orthogonal woven, knit, braid, nonwoven) and packaging density (open or solid) (13)
Staple or filament fibers are used in manufacturing of textile reinforcement while woven fabrics (2-D or 3-D), hybrid fabrics (made of more than one type of fiber or

yarn), braided structures, knitted fabrics, warp knitted fabrics, nonwovens and laminates are used as textile reinforcement.
Two major steps in manufacturing of composites are wetting of textile reinforcement structure with resin (matrix material) and curing, which is three-dimensional formation of a polymer network. During curing, hardening of the resin takes place and bonding is formed between the resin and the fibers in the reinforcement structure (consolidation). Curing can be done unaided or with application of heat and/or pressure for faster polymerization.
The advantages and applications of textile composites are as follows:

- Energy savings are important. Low energy cost during manufacturing and long term energy saving due to lighter components. The energy cost of producing composite automobile body is 40% less than that of a steel body.
- Due to anisotropic design, directional properties could be defined.
- Good fatigue resistance is an advantage.
- Composite parts can be designed with varying degrees of electrical and thermal conductivities.
- The availability of a wide range of fibers, yarns, fabrics, matrix materials and manufacturing processes for reinforcement fabrication and composite consolidation allows flexibility in designing various components and structures.

The current application of composites can be summarized as;

- In automotives: Doors, wheels, trunks, side rails, oil pans, transmission support etc.
- In defense industry: Lightweight, mobile, easily transportable vehicles for tactical shelters, ballistic combat and logistic applications.
- In aircrafts and aerospace applications: Where high strength-to-weight ratio is required, in planes for reinforcement instead of metals. Space structures such as missiles, rockets and satellites.
- In supporting goods: In golf carts, hockey sticks, tennis rackets, fishing rods, water sports, ski equipments, textiles are also increasing at the expense of wood and metal.
- House hold materials, electronic equipments, construction materials, roof covers, floor covers, isolation materials, cargo carriers, packaging materials, ships, containers are the other application areas of textile composites.

9. FUNCTIONAL SPORTSWEAR

Textile materials are used in almost every sport facilities and equipment. High performance textile fibers and fabrics are widely used in sports garments. For example swimwear, skiwears, gymnastics uniforms are made from PUR fibers, which are called Spandex, Lycra and Elasthane as commercial brands, that can stretch up to five times its original length. These fibers can be blended with other natural fibers.

In our daily life, we prefer cotton garments for every active sports; however the moisture on the garment, which occurs as a result of sweating, makes the garment heavier. Owing to this, in sportswear, the synthetic fibers that do not retain moisture are preferred. There are three major requirements in today's sportswear. These are respectively, protection from wind, water and weather conditions, vapor permeability (It is essential that body vapor should be passed outwards through all layers of cloth), stretching property (Movement freedom should be provided in sports).
The use of textile structural composites in sport equipments also increases. Textile composites are used as, for instance, roller blades, bike frames, golf equipments, tennis rackets, ski and surf equipments, baseball and soccer balls.
Functional clothing system, called "mobile thermo", which provides the adjustments of the distribution of heat and temperature at three levels 38^0, 34^0 and 30^0 in uniforms, is used in sports garments. In addition, by applying special finishing processes, required performance properties of fabrics are improved. For instance, breathable fabrics are developed by using PVC microporous coatings.
In recently, the sportswear, that absorb the sweat and dry fast, are getting importance. These clothes have variations such as "fieldsensor", "cubesensor", "coolmagic" and "aerosensor". In addition, sportswear, both functional and hygienic properties must exist together. 100% PES fabrics spread unpleasant odors besides ease of care and quick drying properties. Because of this, sportswear are treated with antimicrobial finishing processes to reduce the odor formation.
Owing to the permanent reduction of the ozone layer, ultra-violet protection has become very important. Consequently chemicals against ultra-violet protection are widely used in sportswear. (17, 18)

CONCLUSION

Technical textiles have a critical role in production of military equipments, medical materials and also in space industry. These products contain high performance fibers such as Kevlar, Nomex, Carbon and widely used fibers such as PES, PA; Cv, glass, etc. According to researches, these special fibers are used only 2-3% of the technical textiles. Even though the percentage of the high performance fibers is lower than the other synthetic fibers, technical textiles have 36-40% in Japan, 30% in America, 20% in Western Europe as the share in textile industry. In 1985, the market share of technical textiles was 50 billion $ and it is estimated to be 72,4 billion $ in 2005. In addition, the proportions with respect to the countries are estimated as 25,9 billion $ in Asia, 18,9 billion $ in America, 15,7 billion $ in Western Europe. (20, 21, 23)
It is obvious that technical textiles have increasingly more application fields day by day and take an important role in our daily life.

REFERENCES

1. ASTM 4439, Koermer, R.M., 1998, "Designing with Geosynthetics", (www.drexel.edu/gri/gmat.html)
2. Adanur, S. (ed.), 1995, "Wellington Sears Handbook of Industrial Textiles".
3. Adanur, S., 2001, " Handbook of Weaving".
4. Bernstein, U., 1996, "microfiber Textiles for Protective Clothing with Barrier Properties", ITB Nonwovens, Industrial Textiles 3, 9-11.
5. Böhringer, A., Rupp, J., Yonenaga, A., 2000, " Antimicrobial Textiles", ITB International Textile Bulletin, 5, 12-30.
6. Brunnschweiler, D., and Hearle, J. (ed.), "Polyester", The Textile Institute, 1993.
7. Byrne, C., 1995, "Technical Textiles", Textile Magazine Issue 2, David Rigby Associates
8. Chandramohan, G., Chellamani, K.P., 2000, "Protective Textiles", Colourage, Texindia Fair Special, 15th-17th, September, 41-54.
9. Cireli, A., Kutlu, B., 2000, "Yüksek Performanslı Lifler ve Askeri Kullanım Olanakları", Levazım Maliye Symposium, 16-17 November, Istanbul.
10. Cireli, A., "Isıya ve Aleve Dayanıklı Koruyucu Giysiler", Tekstil Teknik, December, 181-187.
11. Crown, E.M., Gonzalez, J.A., 1995, "Electrostatistic Characteristics of Thermal-Protective Garment Systems at Various Low Humidities", J. Text. Ins., 549-557.
12. Helmer, A., 2002, "Applications of Nonwovens and Fiber Structures in The Car and Their Acoustic Performance", Melliand International, Vol 8., March, 60-62.
13. Ko, F.K., 1989," Three-Dimensional Fabrics for Composites", in Chau, Technical Textiles and Ko, F.K., eds., Textile Structural Composites, Elsevier.
14. Ko,L.L., Shibamoto, T., Sun, G., 2000, "A Novel Detoxifying Pesticide Protective Clothing for Agricultural Workers", Textile Chemist and Colorist, February, vol.32, No. 2, 34-38.,
15. Kroschwitz, J.I. (ed.), 1990,"Polymers: Fibers and Textiles, A compendium, Enclopedia Reprint Series", John Wiley&Sons.
16. Masurove, J., 2000, "Koruyucu Giysi ve Askeri Kumaşlar için Talepler", Tekstil Teknik, September, 158-163.
17. Rupp, J., 1998, "Functional Sportswear", ITB International Textile Bulletin, No:4, 14-20.
18. Rupp, J., "1999, "Interactive Textiles Regulate Body Temperature", ITB International Textile Bulletin, No:9, 58-60.
19. Schmalz, E., Bottcher, P., 1991, "Nonwovens as Filtration Textiles", 4, 28-34.

20. Trends in the Western European Market for March, 1998, Protective Clothing, Technical Textiles International, 15-20.
21. "Geleceğin Tekstil Ürünü Teknik Tekstiller", Tekstil Maraton, Issue:60, May-June, 3/2002
22. www.davidrigbyassociates.co.uk
23. www.trcs.he.utk.edu
24. www.otokatolog.coms

ADVANCES IN ROPE TECHNOLOGY

J. W S Hearle
Emeritus Professor of Textile Technology, UMIST, Manchester, UK
Senior Consultant, Tension Technology International

ABSTRACT

The technology of making three-strand ropes from natural fibres was developed in ancient times, and changed little until the middle of the 20th Century. The Industrial Revolution introduced factory machinery, but its main effect was to make steel wire ropes dominant in engineering applications. The advent of nylon, followed by polyolefins and polyester, led to manufactured fibres dominating rope production. Braided ropes and low-twist constructions became widely used. The need for moorings of oil-rigs in depths of 1000 to 3000 meters brought collaboration between rope and fibre experts and marine engineers in an engineering design culture, which addressed the problems of fibre rope properties. Polyester ropes with break loads of 1000 tonnes or more have been used in about 20 installations off the coast of Brazil. Software was developed to model tension/torque responses of ropes and the effect of long-term cyclic loading. High-performance fibre ropes are replacing steel in many marine uses, but are held back in land-based applications by the conservatism of civil engineers.

History of Ropes

Traditional Rope-Making

At different times in different parts of the world, men and women discovered that they could take fibres found in nature, twist them together to make long, strong yarns, and then twist the yarns together to make thicker ropes. A fish net found in Finland dates from 10,000 years ago; ancient Egyptian wall-art shows the use of ropes and its manufacture; a rope made of papyrus in 500 BC was found in caves in Egypt; and Herodotus describes how Xerxes crossed the Hellespont on a bridge of boats lashed to six cables, two of flax and four of papyrus. The technology established by ancient civilisations hardly changed until the middle of the 20th century.

Every sort of flexible strand has been used to make ropes in some place at some time. However, the natural plant fibres, composed of cellulose, dominated rope production in historic times. In temperate climates, the bast or soft vegetable fibre, hemp (*cannabis sativa*), extracted from the stem of the plant, was most widely used, with some use of flax. In the 19^{th} century, manila hemp, sisal and other hard vegetable fibres, which were extracted from the leaves of tropical plants, were imported into Europe and USA and used in the industrial production of ropes. Cotton was used for cheaper, soft ropes, where strength and durability were less important. The distribution of consumption among fibres in 1951 is illustrated in Table 1.

Table 1. Consumption of cordage fibres in USA in 1951, from Himmelfarb [1].

Fibre	Consumption in million pounds per annum
hard fibres	
sisal (agave)	121
manila hemp (abaca)	94
henequen (agave)	57
soft fibres	
jute	45
cotton	13
flax and hemp	13
istle	1
nylon	0.6
TOTAL	344

Short fibres were hand-spun into yarns. The remaining stages of ropemaking were carried out discontinuously, most commonly on a ropewalk. At one end, there is the jack, which has three hooks that can be rotated. At the other end there is a carriage with a single, rotatable hook. The required lengths of yarns are pulled into the ropewalk; rotation of the three hooks forms the strands; and then rotation of the single hook forms the rope. There are complications of twist, contraction and packing, and that brief description hides the skill of the ropemaker in making a well-formed rope. Figure 1 illustrates the structure of three-strand ropes, taken from the authoritative mid-20^{th} century book by Himmelfarb, Master Ropemaker of the US Navy Ropewalk [1].

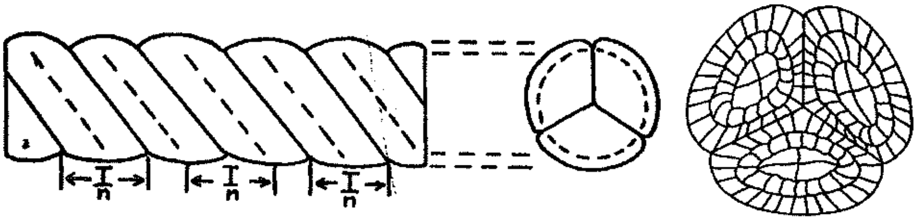


Fig. 1 Three-strand rope structures, from Himmelfarb (1957).

The Industrial Revolution, circa 1800, brought yarn production into factories and, later in the 19th century, continuous rope-making machines, were developed as an alternative to ropewalks. Braiding machines were also made and this became a common method of making cords and some small ropes. The most important consequence of the Industrial Revolution for the rope industry resulted from the development of steel wires. These could be assembled into wire ropes and cables, which came to dominate the engineering applications, such as bridge-cables, mine-hoists, elevators, cranes, as well as the heavier-duty cables for traditional uses, such as shipping and forestry.

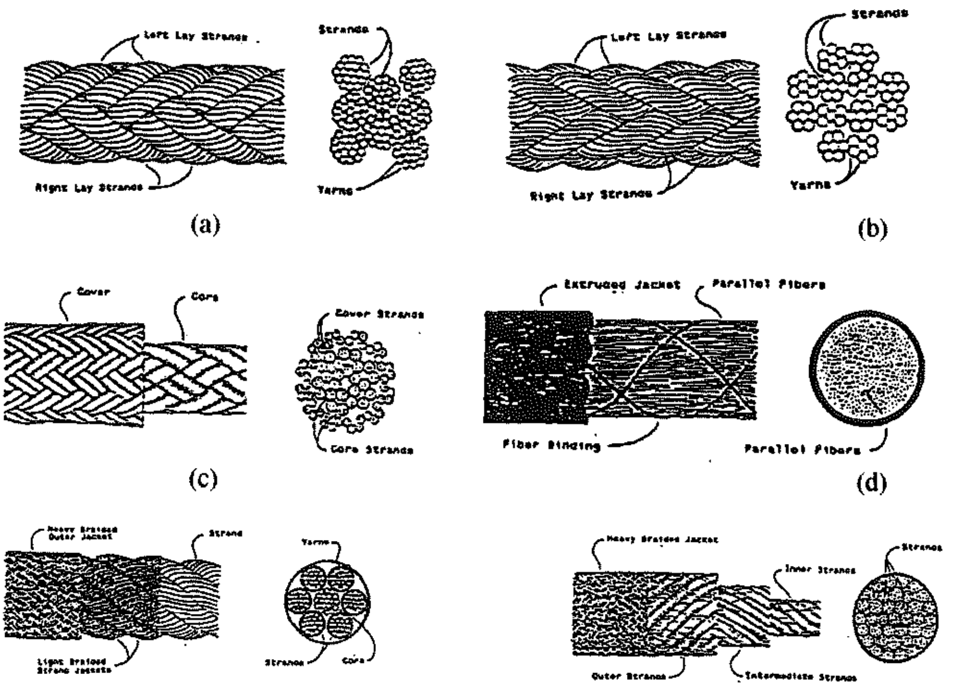
Changes in the 20th Century

Great changes in rope technology followed the invention of nylon, which began to be used in cordage in the Second World War. By 1950, larger three-strand nylon ropes were being made, but, as shown in Table 1, nylon accounted for only 0.16% of the total cordage consumption in USA in 1951. Now synthetic fibres dominate the rope industry, though natural fibres remain important in some uses such as sisal baler twine.

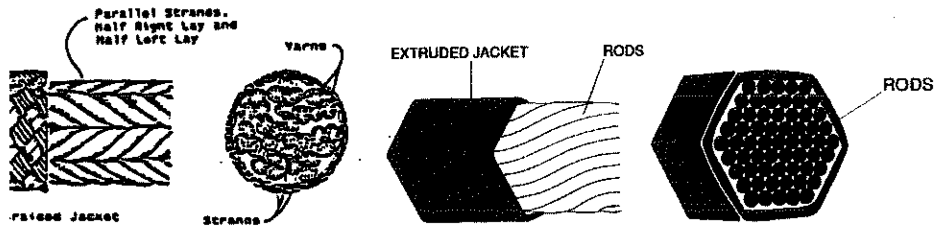
The next synthetic fibres to come strongly into rope production were the *polyolefins*, polyethylene (polythene) and polypropylene, which replaced natural fibres in the cheaper, commodity rope market. Although *polyester* fibres were produced before polypropylene, thier use in ropes followed later, after the development of strong, industrial yarns. For many years, nylon remained the premium rope fibre, because of its strength, extensibility and toughness; but polyester has now overtaken nylon in high-performance ropes, except where a lower modulus (less resistance to extension) or good recovery from high stresses are required. The coming of the high-modulus, high-tenacity (HM-HT) fibres, aramids, HMPE and PBO, led to ropes with higher strength and stiffness, but at a high price. Linear-polymer fibres yield in compression, which is a limitation, but means that in ropes the fibres can be severely bent without breaking.

Nylon was first used in the traditional three-strand construction, Fig. 1, with which ropemakers were familiar. This is still a common rope type, but new rope constructions were introduced in the second half of the 20th century. Because synthetic fibres are continuous filaments of effectively infinite length (it is always possible to wind one more turn on a package!), twist is not strictly needed. In principle, a collection of parallel filaments could act as a tension member. In practice, they would spread out, might become entangled and would be susceptible to breakage of individual filaments by abrasion. Some coherence must be given to the bundle to make a useful rope. The principal modern rope types are illustrated in Fig. 2.

The first development was associated with the production of large braiding machines. Himmelfarb [1] refers to braids only in the context of cords up to 1 cm in diameter with break loads of 250 kg. A modern catalogue would typically go to the 10-cm diameter, 250 tonne break load category, and would include 8-strand ropes, Fig. 2(a), 12-strand



(e) (f)



(g) (h)

Fig. 2 Modern rope types. (a) 8-strand braided. (b) 12-strand braided. (c) Braid-on-braid. (d) Parallel yarn. (e) 6-round-1 wire-rope construction. (f) 36 strand wire-rope construction (18+12+6+1). (g) Parallel-strand. (h) Pultruded rod.

ropes, Fig. 2(b), and double-braid ropes, Fig. 2(c).

If fibres lie at angle to the rope axis , there is inevitably a loss of strength and stiffness, compared to the fibre values. In order to overcome this problem, ICI developed *Parafil* ropes in the 1960's. An assembly of parallel yarns was enclosed within a plastic jacket, Fig. 2(d). Parallel-yarn ropes are good for some applications, such as antenna stays, but their high bending stiffness limits their uses. Rope manufacturers looked instead for low-twist constructions. If the angle of lay θ is kept below 10°, the simple $\cos^4\theta$ expression indicates that the strength loss should be less than about 5%. This level of interaction gives coherence to fibre assemblies, but allows some freedom in bending.

In the 1970's, wire-rope constructions, Fig. 2(e, f) were adopted for fibre ropes. These consist of counter-directional layers wound on top of one another with long lay lengths.
Later in the 1970's, parallel strand ropes, Fig. 2(g), were introduced. A core, consisting of a number of low-twist, three-strand sub-ropes, was enclosed within a braided jacket. A later variant used long-lay braided sub-ropes in the core. These are the types of ropes used for the deepwater moorings of oil rigs with diameters in polyester up to more than 20 cm for strengths of 1500 tonnes.

In another construction from the 1970's, filament yarns were pultruded with a resin binder, so that they made composite "wires", which could be assembled these within an extruded jacket, Fig. 2(h). This technique can be used with polymer fibres, but its main potential is that it gives a way of making glass, carbon or even ceramic fibre ropes.

Advent of Engineering Design

Deepwater Mooring

The advances described above, mostly in the 3rd quarter of the 20th Century, followed the path of creative empirical development, which has been typical of the textile industry. The 4th quarter brought a change of culture to one that is characteristic of engineering industries. The US Navy had ideas for mooring large, floating platforms where they were needed for emergency operations, though these ideas remain on the drawing board. In addition to testing, they contracted TTI to produce software to model performance. A more pressing demand came from oil companies, who wanted to expand production to greater depths. Steel wire is fine up to 500-meter depths, but is too heavy for 1000 to 3000 meters. Fibre ropes offered an alternative, but were untried. This has led to a number of Joint Industry Projects related to the use of ropes for oil-rig moorings and to the production of *Deepwater Fibre Moorings – an engineers' design guide* [2]. In preparing this guide, fibre rope experts with a fibre and textile background had to work with marine engineers, who were more used to steel, on the ways in which the complicated properties of polymer fibre ropes could be used as inputs to mooring analysis software. Polyester is the most suitable material. In a displacement-driven system, high-modulus fibre ropes generate too high a tension.

An example of the advances is the installation since 1995 by Petrobras of polyester ropes on about 20 rigs off the coast of Brazil. For the P36 rig with 16 lines, each 1800 meters long, diameter of 175 mm, weight of 23 kg/m (23 Mtex), with 1000 tonne break load, this uses over 600 tonnes of polyester yarn.

Modelling Tension and Torque Response

The modelling of structure geometry follows a hierarchical approach. The basic components, usually "textile yarns" as supplied by the fibre producer or rope yarns assembled by the ropemaker, are specified in terms of: linear density (mass/length); fibre density, packing factor, which give diameter; tensile stress-strain properties; and coefficient of friction. Higher levels, such as strands and sub-ropes, are then built up to mirror the manufacture of the whole rope. Starting from the basic components, the properties of each level are used as inputs to the next higher level. Three forms of arrangement of components are considered: "packing" geometry, with circular components in contact radially; "wire-rope" geometry, with circular components self-supported by circumferential contact forces; "wedge" geometry, with components are deformed to pack without spaces.

The basic deformation assumption is that planes perpendicular to the axis of the helical structure within each component remain planar and perpendicular to that axis. Analysis by differential geometry gives expressions for the elongation, twist and lateral contraction of the lower level components, and keeps track of the sequence of imposed deformations through the several layers of the structure. In order to introduce frictional effects, it is necessary to consider slip in various modes at contact points.

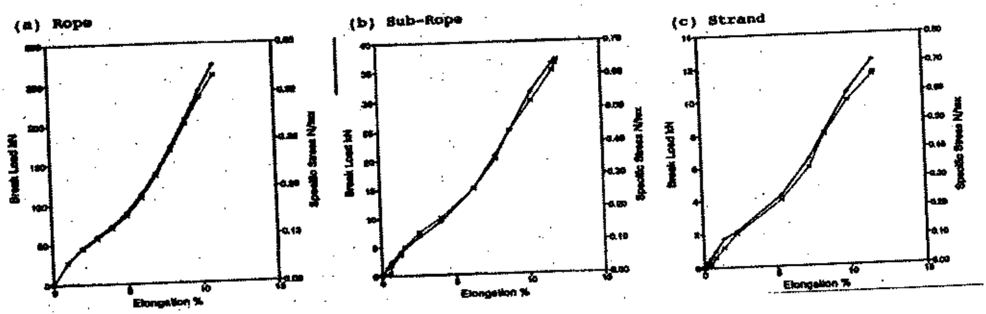


Fig. 3 Experimental (crosses) and theoretical (circles) load/elongation curves for parallel strand polyester [3].

The analysis of the mechanics is based on the Principle of Virtual Work, taking account only of fibre elongation energy. Application of virtual displacements gives the expressions for tension and torque. In order to determine contact forces between components in the structure, it is necessary to introduce virtual changes in the helix radii. The frictional force is given by multiplying the contact force by the coefficient of friction. The frictional contribution to the deformation energy is small and could be neglected, but contact effects are important in cyclic loading. The analysis outlined above enables tension and torque in ropes to be calculated as functions of elongation and twist. Breakage occurs when the input components, normally yarns, reach their breaking extension. A number of measurements of tension and torque developed in ropes, strands and yarns have been performed in order to confirm the validity of the theory and computer codes [3]. Figure 3 shows the good correlation between theory and experiment in load/elongation curves for all three levels (the rope itself, a sub-rope and a sub-rope strand) of a parallel strand polyester rope.

Cyclic Loading

One of the problems for engineers, who are used to dealing with well defined metal structures, is the way in which fibre rope dimensions and properties change. Changes in length and stiffness are due to two causes: (1) tightening of rope structures; (2) viscoelastic fibre properties. For an ideal elastic material, stiffness is uniquely given by size and modulus. For fibre structures, it is not so simple, due to the viscoelasticity of the material, frictional slip between components, and bedding-in of the structure. In general, stiffness will depend on mean load, cyclic load range, previous loading history, temperature etc.

For oil-rig mooring, there are two important consequences of wind, wave and current: offset, which must not exceed the allowable drift of the vessel from its intended station; peak load, which must be below the rope break load by a required safety margin. Environmental data can be fed into mooring analysis programs to compute the forces on the vessel, but the system response depends on interaction with the mechanics of the mooring lines. Steel wire moorings follow a catenary and the forces result from the weight of the rope. Fibre moorings are different so that new analyses had to be developed. The lines are taut and the forces come from the tension in the ropes. We need to know: the zero-tension rope length, which changes due to creep; the quasi-static modulus, which gives the mean extension; the cyclic modulus.

Fatigue

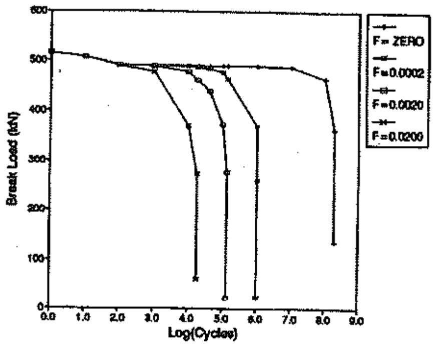
The other important factor is long-term durability. Polymer fibres do not suffer from the crack-propagation fatigue mechanism that occurs in metals, but there are other potential failure mechanisms. The TTI programs for the US Navy were extended to cover life prediction. The basic principle of fatigue modelling is that the changes in material properties, as a result of the cyclic loading, can be determined and used as the input for the rope response in the next cycle. It would take too much computer time to compute the response in every cycle of a long lifetime of use. The scheme adopted therefore computes the response for batches of cycles, in which the response is assumed to be negligibly changed. The fatigue effects that have been taken into account in the modelling are: creep and creep rupture; hysteresis heating; internal abrasion; and axial compression fatigue. The software provides effective modelling; but input data on some fibre properties, such as abrasion resistance, is lacking.

Creep is a factor that needs to be checked for HMPE ropes. With the usual safety factors, creep rupture is not a problem for other fibres, though it becomes the final predicted failure mechanism when the number of functioing fibres is reduced. In long-term installations, creep makes it necessary to periodically re-tighten ropes. Internal abrasion is a serious problem with wet nylon ropes, but is much less in polyester ropes.

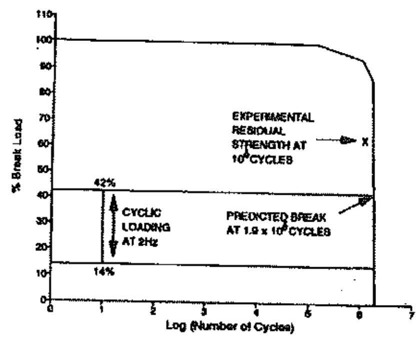
As described by Hearle et al [4], the computer code provides values for the heat generation due to fibre hysteresis and frictional losses and also uses a summation of the heat flow from different sources to compute the temperature changes. Account can then be taken of change of fibre properties with temperature. Cyclic testing [5] of large ropes immersed in sea-water has shown that for strain amplitudes less than 0.25% little heating occurs. This strain amplitude is equal to the axial strain induced in a taut fibre mooring in 1500 m water depth in a severe environment (100 year return period). Thus the conclusion was that hysteresis heating would not be a problem for full-scale deepwater moorings. However, for shallow moorings the strain amplitude is far higher, and, since the fibre loss factor increases rapidly with strain amplitude, this may lead to appreciable heating. In a severe application, such as KERR (kinetic energy recovery ropes), which are used to drag heavy vehicles out of trenches, fibre melting can occur, and single-point mooring ropes (SPMs) have been reported to be steaming.

Axial compression fatigue was responsible for a failure in an early use of Kevlar rope. Lines to moor a construction derrick ship were predeployed in the Gulf of Mexico 4 to 6 weeks before the vessel was due. When the lines were picked up, some broke. Tests showed that the ropes retained only 20% of their initial strength. The problem was that cyclic motion due to waves caused the ropes to twist, so that some components went into compression. The resulting kinking of yarns leads to failure by flex fatigue of the Kevlar. Lessons were learnt from this event that gave better rope constructions and advice on use. Axial compression of components in a rope under low tension can occur, even when most components are under tension, if the rope twists, if there is length variability among components, or if a tight jacket takes the tension. This introduces an unexpected minimum-tension requirement for rope use. A guidance limit [2] for deepwater moorings is that aramid ropes should not go below 10% of break load for more than 2,000 cycles, HMPE for 40,000 cycles, and polyester below 5% for 100,000 cycles. The theory of kinking due to axial compression has been given by Hobbs et al [6].

Figure 4(a) presents the predicted fatigue plots of residual strength against log(time) with different values of the local abrasion rate of wear parameter *F*, on a 7 strand aramid rope cycled at wave period (6s or 0.167Hz) between 16% and 45% of its predicted new breaking strength. The initial drop is due to hysteresis heating to 72EC in the core strand and 32EC in the outer strands, which reduces the break load. With *F* = zero the predicted lifetime is almost 202 million cycles (40 years) and failure results from creep rupture. The rapid drop just before final breakage is typical, and is due to the cumulative action of break of some fibres increasing the load on others. As *F* is increased, abrasion leads to an earlier onset of the final reep rupture.
Figure 4(b) presents the predicted fatigue plot of residual strength against log(time) with global abrasion parameters (**a** = 10.009 and **b** = -0.107) for a 5 tonne aramid rope cycled at 2Hz between 14% and 42% of its predicted new breaking strength. The progressive reduction of break load takes account of the effects of creep rupture, hysteresis heating and abrasion damage. The experimental point shown depicts the residual strength of a rope which was removed from a test after it had survived 1 million cycles.



(a)



(b)

Fig. 4 (a)Predicted residual strength throughout lifetime with local abrasion, for 7 strand aramid rope. (b)Predicted residual lifetime, with global abrasion for aramid wire rope construction.

CONCLUSION

The familiar uses of ropes, which have been around for hundreds and thousands of years, continue today. A major change in the last quarter of the 20th century was a move into more demanding engineering applications. This was triggered by the high strength of the second generation of synthetic fibres, which were appreciably stronger than steel on an area basis and vastly stronger on a weight basis. Joint industry studies were set up to evaluate ropes for deepwater moorings, which led to the conclusion that the modulus of polyester matched the needs better for this growing market. The use of fibre ropes in demanding engineering applications has led to a change of culture, which contrasts with the age-old basis of craft experience and trial-and-error. For the first time in the history of textiles, manufacturers have had to adopt an engineering-design approach, which expects calculations to be done and quantitative design data to be specified and predicted.

In more traditional uses, such as towing and docking, fibre ropes are replacing steel because their light weight and softness make for easier and safer handling. This is not only welcomed by crews, but also proves economic for owners. In marine applications, the advantages of fibre ropes over steel are now well recognised. This is not true of land-based civil engineering. Potential benefits can be shown - for example, Cook et al [7] showed that, for a large-span structure, cable weights in aramid would be a quarter of those in steel with considerable overall cost-benefit improvement - but conservatism prevails. Engineers are reluctant to try a new material.

REFERENCES

[1] Himmelfarb D The Technology of Cordage Fibres and Ropes, Leonard Hill, London, 1957.

[2] Tension Technology International and Noble Denton Europe, *Deepwater Fibre Moorings – an engineers' design guide*, Offshore Publications Ltd., 1999.

[3] Leech, CM, Hearle, JWS, Overington, MS and Banfield, SJ , Modelling Tension and Torque Properties of Fibre Ropes and Splices, *Third) International Offshore and Polar Engineering Conference, Singapore*, 1993.

[4] Hearle, J.W.S., Parsey, M.R., Overington M.S. and Banfield S.J., Modelling the Long Term Performance of Fibre Ropes, *Third (1993) International Offshore and Polar Engineering Conference, Singapore*, 1993.

[5] TTI and NEL, JIP promoters, The testing and optimisation of full scale fibre FPS mooring lines, January 1997.

[6] Hobbs R.E., Overington M.S., Hearle J.W.S. and Banfield S.J., Buckling of fibres and yarns within ropes and other fibre assemblies, *J Textile Inst*, **91** 335-358. 2000.

[7] Cook M.J., Happold E., Liddell W.I., Hearle, J.W.S., Hobbs R.E. and Parsey, M.R., Technical/economic evaluation of cables for long-span structures, *IABSE Symposium*, Birmingham 25-30, 1994.

TIME-DEPENDENCE BEHAVIOUR OF TIRE CORDS

A.S. Hockenberger, S. Koral
University of Uludag, Department of Textile Engineering, Bursa

1. INTRODUCTION

PET fibers of high modulus and tenacity are used in industrial applications such as reinforcements for rubber articles (i.e tires and hoses), geotextiles, ropes. High modulus and Low shrinkage (HMLS) PET yarnswith this unique combination of properties have been prepared previously by subjecting drawn yarns to thermal treatment procedures. The PETfibers of this investigation are unique in that no thermel treatment is necessary to achieve the low shrinkage [1].

Polyethylene napthalate (PEN) is a high-performance, high-priced polymer with with oppurtunities in several areas. Characteristic features of the molecular structure of PEN are the rigidity of the polymer chains and the occurance of two trans conformations of the naphthalate ring [2].

Both polyesters are semicrystalline with closely similar melting temperatures. Differences in the physical properties of PEN and PET have generally been attributed to the assumed increased rigidity conferred on PEN by its constituent naphthyl rings, which are clearlr larger than the phenyl rings in PET [3].

The requirements for a tire cord may vary with the basic type of fibre reinforcement. For a tire carcass, the required fibre properties are high tensile strength, good fatigue and durability, dimentional stability, low heat generation, and low growth and creep [4].

In this study three very important and mostly used tire cord yarns have been investigated in terms of mechanical performance and an understanding of how cord configuration impact final cord properties has been established.

2. EXPERIMENTAL

2.1 Material and Tire Cord Preparation

In this study 3 different tire cords namely PEN 1X53, PET 1W70 and PET 1X90, produced by Allied Signal Industrial Fibers were used. Here PET 1x90 is Dimentionaly Stable (DSP) Polyester tyre cord yarn used in applications which demand high modulus and low shrinkage and PET 1W70 is a conventional high modulus and high tenacity fiber. The cord properties is given in Table.1

Table 1. Cord Properties

PRODUCT	PEN	1X90 DSP PET	1W70 Regular PET
DTex	1110	1100	1100
Filament Count	140	300	192
Tenacity (g/d)	10.2	8.0	8.1
Elongation at break (%)	6	11	14

* Producer's specifications

Tire cords were prepared by twisting the yarns into 2 ply construction with 4 different twist levels of 350, 445, 470 and 530 turns/m by direct cabling equipment No thermal process was applied to the cords throughout this study. The tire cords were in greige form.

2.2 Experimental Procedure

2.2.1 Tensile Tests

Tensile tests were performed by using INSTRON tester 4502 at a cross head speed of 300mm/min with a gauge length of 254mm.. Table.2 shows the breaking elongation and breaking strength values. The results are presented as stess-strain curves and the breaking extension and breaking strength values are tabulated.

2.2.2 Creep Tests

Creep tests have performed by means of dead loading conditions. The cords were attached with a pin from one end the dead load was applied to the other end. % 20 of the breaking strength of cords was applied as creep load. Every five minutes, the elongation in the length has been measured by a graded ruler hanged next to the cord. To prevent turning and changing the position of the loaded cord a special mechanism was attached to the specimen through the load. The results are presented as elongation against time under constant load.

3.RESULTS AND DISCUSSION

3.1 Tensile Results

Representative stress-strain curves for the 3 different cord yarns of this investigation, 1W70, 1X90 and PEN with 4 different twist levels are shown in Figure.1,2,3. The tensile tests results are given in Table.2.

Table 2. The Tensile Test Results

Cord Type	Twist Level TPM	Breaking Strenght (KN)	Breaking Elongation (%)
PEN	350	0.169	8.374
	445	0.149	9.647
	470	0.144	9.841
	530	0.125	10.594
1X90	350	0.150	14.431
	445	0.141	15.384
	470	0.145	16.960
	530	0.138	18.746
1W70	350	0.162	17.363
	445	0.165	20.747
	470	0.157	20.030
	530	0.153	21.400

When the stress-strain data of cord yarns with 4 different twist levls are analysed, an increase in breaking extension and a decrease in breaking strength are observed. In textile yarns twist is applied to yarn to increase tensile strength and for a maximum tensile strength always an optimum twist level where strength decreases is exist for each type of material (Figure.1). An icrease in twist level puts extra stress on the yarn and increases fibre to fibre friction. This can be explained by considering the effect of stresses on the cord as the twist increases. As twist increases, the helix angle (angle between the filament axis and cord axis) increases. Thus, tension stresses normal to the cord axis result in greater force parting filaments. As cord twist increases, the force in the direction of the yarn axis increases, causing a lower overall breaking strength. A highly twisted cord will behave like a coil spring. It will give relatively low cord strength but high fatigue resistance. In contrast, a slightly twisted cord will act more likea rod. It will give higher strength but poorer fatigue resistance. This also explains the increas in elongation at break with increasing twist. Therefore in cords in order to have high performance properties and better fatigue behaviour, twist levels are preferred beyond the optimum twist level explained in Figure 1.

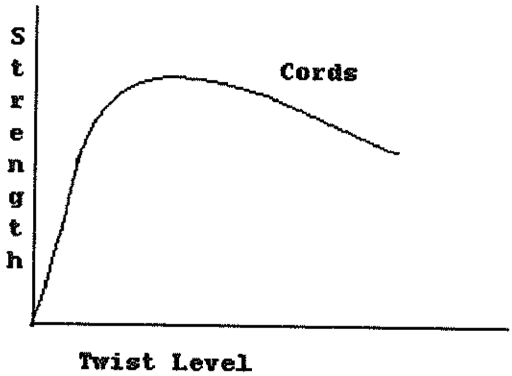


Figure 1

Stress-strain curves of PEN cords with 4 different twist level showed two distinct regions (Figure.2). First region is the elastic region including the yielding and the second region shows the strain hardening leading to rupture.. First region showed no considerable change in shape due to increased twist level. However, the yield point moved to lower positions and the modulus was decreased. The second region changed with increased twist level. The length of the strain hardening region was increased. In the second region it is thought that each ply of the cord carries load equally and they act together upon loading. Therefore PEN cord yarn with the highest twist level showed rather brittle material behaviour with no distinct yield region.

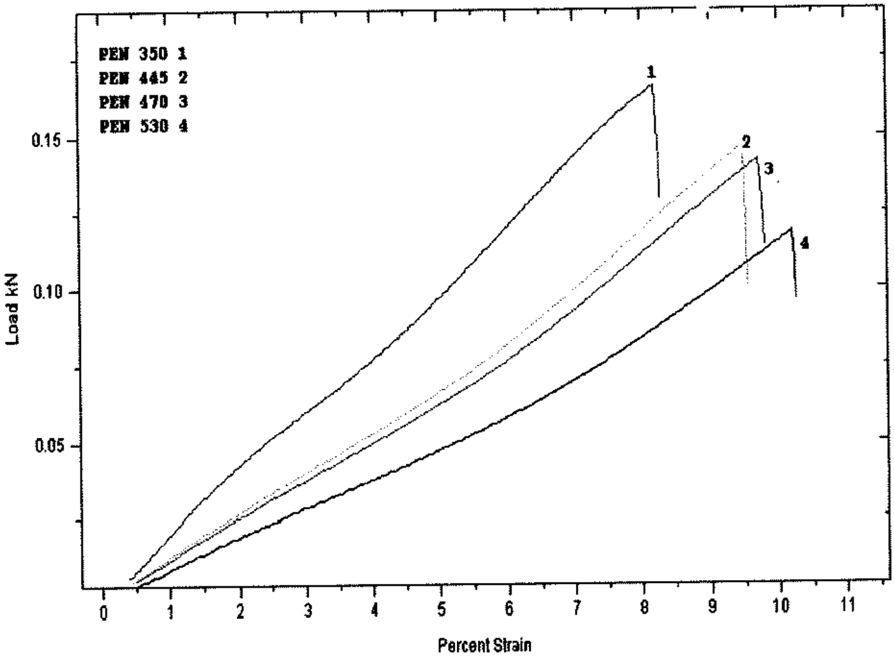


Figure.2

Stress-strain curves of 1X90 polyester cord yarn with 4 different twist level showed typicall ductile material behaviour (Figure.3). Therefore a short hooke region with pronounced yielding followed by strain hardenning was seen. Compared to PEN cords, here more distinct yielding was observed. Also the same pattern of decreasing tensile strength with increasing twist level was recorded.One important point, however, that should be mntioned is, here with twist levels 350 and 445 TPM the changes in stress-strain curves and the breaking elongations are not as obvious as in PEN cords with the same twist levels.

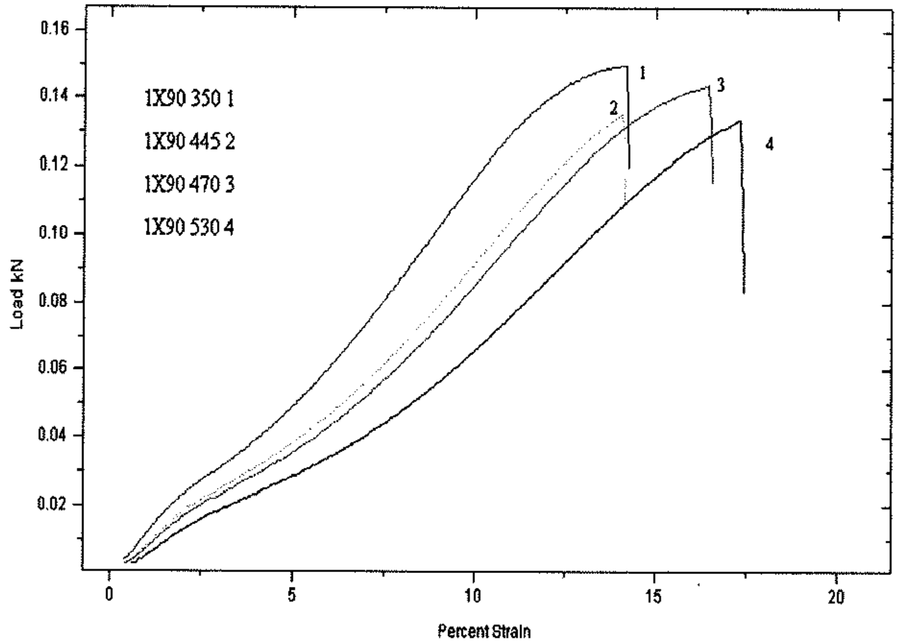


Figure.3

When stress-strain curves of regular PET tyre cords were analysed (Figure.4), It was observed that increasing twist level had not a big effect on the shape of the curves. However, it was not easy to establish a pattern of stress-strain data with incresing twist level. Typical ductile material behaviour was also predominant for 1W70 regular PET tyre cords.

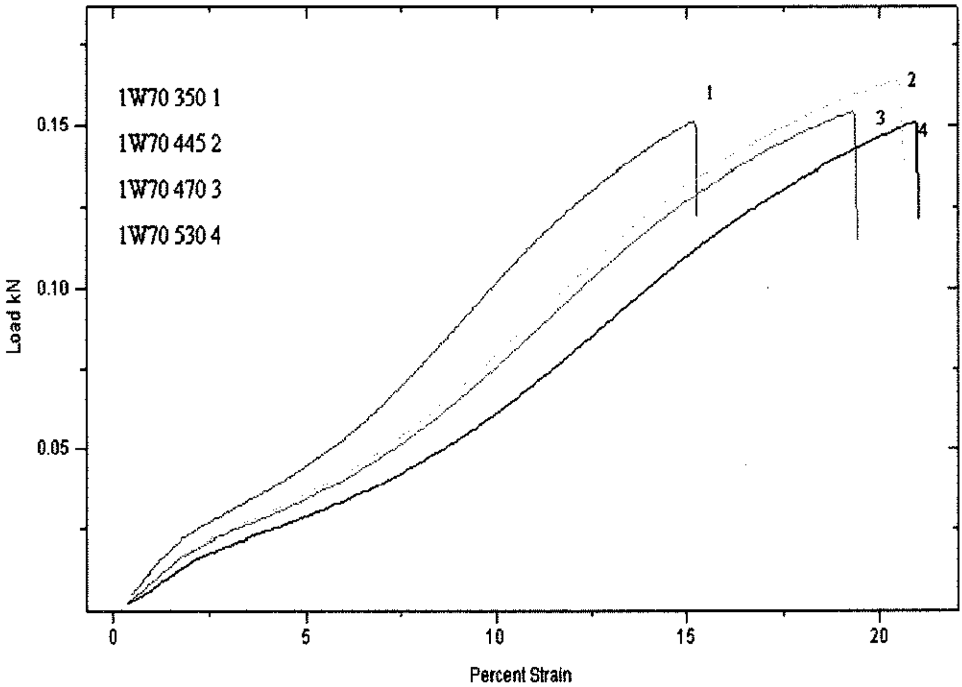


Figure.4

For all the twist levels PEN has the lowest breaking extension. However with the lowest twist level (350TPM) the breaking strength values were almost the same. With increasing tist level, breaking strength of 1W70 regular PET cord was drastically increased and this type of cord was mostly effected by increasing twist level compared to other cords.

3.2 Creep Tests

The aim of this creep tests was to establish a basis for describing and comparing the creep behaviour of PEN, 1X90 DSP PET and 1W70 regular PET tyre cords. An analysis of the changes in the creep behaviour resulting from different twist levels were carried out.

Polymeric materials includig fibres show creep under static loading conditions. In thermoplastis polymers creep can be extensive. Therefore crep analysis plays very important role on performance expectations. Figure.5 shows a ver typical creep curve of a polymer, the elongation of a fibre plotted as a function of time under constant load.

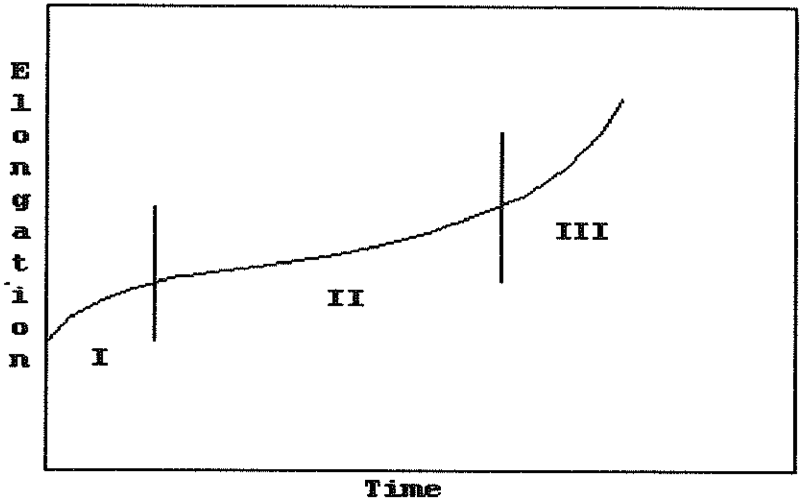


Figure.5

In such an elongation vs. time curve four regimes can be characterised by different behaviour of the creep rate:

- Regime Ia, instantaneous initial elongation
- Regime Ib, creep rate decreases with increasing elongation (primary creep)
- Regime II, creep rate is approximately constant (secondary creep)
- Regime III, creep rate increases again, signalling imminent failure

Initial elongation and the elongation caused by primary and secondary creep are important for the applications of the fibre, therefore this study hasfocused on these regimes.

REFERENCES

1. P.M. Rim, C.J. Nelson; J.of Appl. Polym. Sci.,Vol.42, 1807-1813 (1991)
2. A.E Tonelli, Polymer, 43, 637-642 (2002)
3. C.J. M. Van den Heuvel, E.A. Klop ; Polymer, 41, 4249-4266 (2000
4. F.J. Kovak, Science and Technology of Rubber, Chapter 14, Acedemic Press, New York, 1978

HIGH TECH AND FLAME RETARDANT FIBRES MANUFACTURING TECHNOLOGIES IN THE TEXTILE PROCESS

A. Piccolini , E.Antisso
Fil Man Made Group, Italy

1. INTRODUCTION

The classification of a fibre as, "flame retardant" or "high tech/high performance", is not well defined and rigid.
Before getting into the details on these topics, it is necessary to define what we intend, in the present lecture, for:

- flame retardant fibre.
- high tech or/and high performance fibre.

There is often confusion among flame retardant ability and resistance to heat.

For ability of a fibre to be flame retardant we intend:

- a fibre that measured by Limiting Oxygen Index, needs, for fire ignition, a higher quantity of oxygen, of that it is present in the terrestrial atmosphere to the level of the sea.

For H.T. or H.P. fibre., we intend all those fibres that answer to the followings minimum requirements:

- LOI =/> of a flame retardant fibre.
- Thermomechanical Resistance not less than 60%, after heat treatment at 260°C for 48 hours, or in alternative not less than 90% at 200° C° for 48 hours.
- Degradation Temperature > 370°C
- Melting Temperature > 285°C without softening.

Definition of terms. (1)

Thermomechanical resistance: Percentage of the initial mechanical strength at ambient, after treatment of a given duration at a

	constant temperature in air, or after treatment up to a given temperature in air.
Degradation Temperature:	Characteristic temperature of beginning of sensible weight loss.
Melting Temperature:	Characteristic temperature of the transition of the crystalline phase of a semicrystalline polymer, from the solid state to the liquid state.

2. FLAME RETARDANT AND HIGH TECH. FIBRES. WHAT THEY ARE FROM, WHERE ARE THEY BORN?

2.1 Flame Retardant Fibres.

They are mainly produced by three families of basic polymers:

- From natural modified polymers
  > cellulose – viscose CV (LOI 20) > viscose fr CV (LOI 26/28)
- From synthetic modified polymers
  > polyester PET – PES (LOI 19/21) > polyester fr PET – PES (LOI 28/30)
  > acrylic PAN (LOI 19/21) > modacrylic fr MAC (LOI 28/34)
- From intrinsically flame retardant polymers.
  clorofibre CLF (LOI 38/46)

2.2 High Tech or/and High Performance Fibres.

2.2.1 Organic

They are only produced by engineered synthetic polymers.
The most important, on the market point of view are:

- Aramid.
  Para-aramid (polyparaphenylene terephtalamide) PPTA . (LOI 27/29). Kevlar®, Twaron®.
  Para-aramid (copolymer, polyparaphenylene/3,4'-oxidiphenylene terephtalamide) PPTAC. (LOI 25) Technora®.
  Meta-aramid (polymetaphenylene isophtalamide) PMIA. (LOI 29/32) Nomex®, TeijinConex®.
  Meta-armid (polyamide imide) PAI. (LOI 32) Kermel®.

Meta-armid (copolyimide) PIC. (LOI 36) P.84
- Fluorpolymer. (polytetrafluoroethilene) PTFE (LOI >90) Teflon®, Profilen®.
- Melamine. (melamine formaldehyde resin) MF (LOI 32) Basofil®
- Phenolic. (phenol-aldehide resin) PHE (LOI 30/34) Kynol®
- Polybenzimidazole. (polybenzimidazole) PBI (LOI 41). Celanese PBI®
- PBO fiber.
  Poly-phenylene-2,6benzobisoxazole PBO (LOI 68) Zylon®
- Phenilene Sulphide.
  Poly-phenylene sulphide PPS (LOI 34) Torcon®, Procon®.
- Oxidised polyacrylonitrile.
  Polyacrylonitrile.partially oxydized PANO (LOI>50). Panox®, Lastan®.

2.2.2 Inorganic

- Carbon fibre. > 99,9% carbon CF
- Metallic fibre. 100% stainless steel, 100% silver, 100% copper. MTF
- Glass. GF - Boron. B - Silicium carbide. SiC – Silica Sil.

They have mechanical and chemical characteristics very diversify, for instance:
- Density that varies from 1,2- fenolic fibre, to 2,1-polytetrafluoro ethylene fibre.
- Electric resistivity, that place the carbon fibre at $0{,}8_{-3}$ ohm/cm, in some cases, is near to $10{,}0_{+19}$ ohm/cm, polytetrafluoroethilene.
- Breaking Tenacity that is set from low levels, PBI 24cN/tex to very high, Para-aramid, 220 cN/tex.
- Elongation at break that varies from < 10% - oxidised polyacrylonitrile, to > 100% - clorofibre.

3. CONCEPT OF PROCESSABILITY

1.1 How to Act

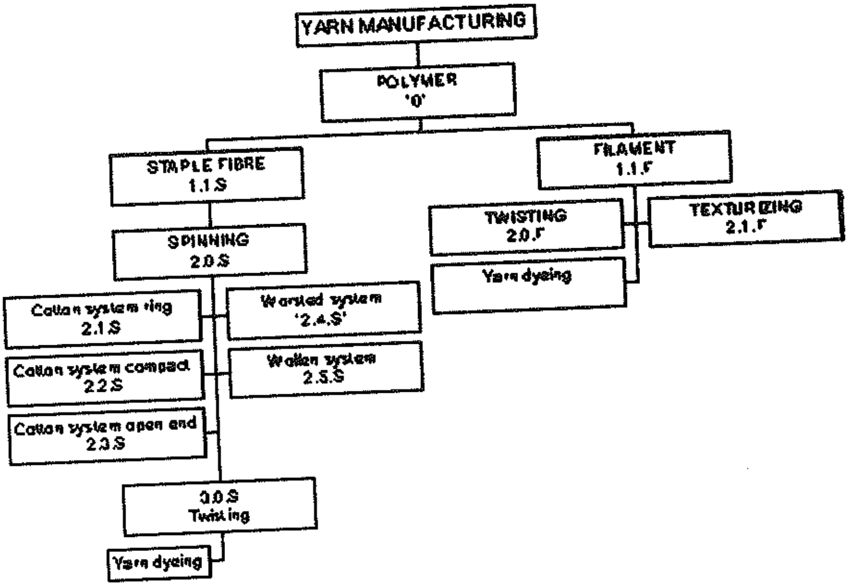
Flame retardant fibres are used, for making spun yarns, both in pure and in intimate blends with other fibres, also not flame retardant.. Mixtures of different yarns, F.R., H.T. and standard, on the loom, are also possible.
F.R. fibres, being not particularly different from the "standard fibres" from which they have been developed, normally don't need preliminary studies or especial trials, for setting the whole textile chain.
For high tech fibres, it is completely different.

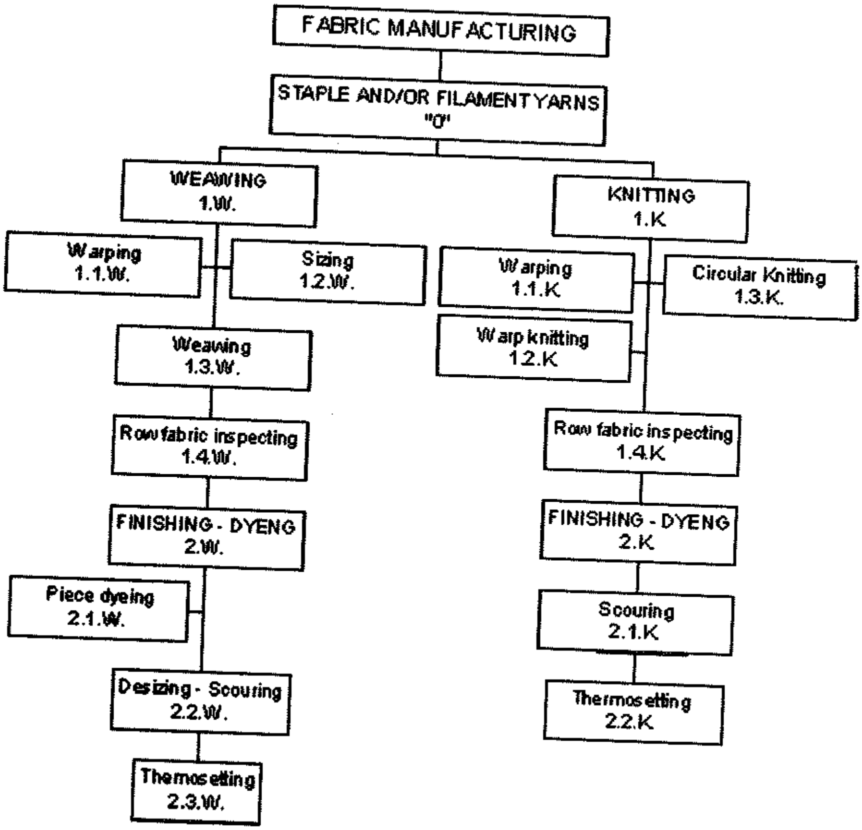
They are very often used in intimate blends, among them, and with conductive fibres as 100% stainless steel, (Bekinox®), or organic synthetic fibres, metallic coated, (R.Stat®, X-Static®, etc.)
H.T fibres are also used to produce core-yarns, with metallic filament or pure carbon filament as core. It is necessary to build stable manufacturing processes, repeatable and economically effective. Owing to the very expensive price of these kind of fibres, (some as PBI and PBO overcome the 200 €/Kg, but also a "normal high performance fibre", as aramide or PPS it is not cheaper than 20-30 €/Kg,) it is not allowed any kind of mistake during the whole textile process. Also the percentage of waste should be close to zero.
For these reasons, the only reasonable way to operate in the whole textile process is:

- To set all the trials on pilot plants. Experimental lines of spinning and/or twisting, warping frames for sampling, as Hergeth or Suzuky, looms devoted to develop samples, laboratory frames of dyeing and finishing
- To fix a first provisional technical specification, both of process and product.
- To transfer, the finished trial products, on the industrial plants, that have to be modified and set, according to the experiences done on the pilot plants
- To do, before starting in industrial productions, a care technical and productive evaluation, of all the bonds emerged during the experimentation.

1.2 As to Overcome The Bonds

Departing from the textile cycle, schematically represented, we go to verify the principal problems in processing the high performance textile products, and to point out the proper technological solutions to solve them.


YARN MANUFACTURING
POLYMER
'0'
STAPLE FIBRE
1.1.S
FILAMENT
1.1.F
SPINNING
2.0.S
TWISTING
2.0.F
TEXTURIZING
2.1.F
Yarn dyeing
Cotton system ring
2.1.S
Worsted system
'2.4.S'
Cotton system compact
2.2.S
Wollen system
2.5.S
Cotton system open end
2.3.S
3.0.S
Twisting
Yarn dyeing



4. YARN MANUFACTURING

4.1 Staple Fibre Spinning (1.1.S. >2.5.S.)

More than 95% of staple fibre high tech yarns, are produced with cotton ring spinning technology. The other systems of spinning are absolutely marginal. Staple yarns produced by "tear system", departing from tow or from continuous filaments, are an interesting nice, but only a nice.
For spinning high performance fibres, it is absolutely necessary a perfect thermal and moisture setting of the spinning mill, with a really efficient air conditioning

plant, able to maintain diversified conditions, among carding, drawing , spinning and twisting.
Most of these products, mainly the blends of different fibres, need, with a standard temperature of 25°C, a quantity of water in the air, that could be in carding, more than 12 gr. for 1Kg of air, and in spinning equal or less than 10 gr. for 1Kg air.
It is essential to use refrigerant plants, also in non warm climates, for an efficient drying of the air.
As, spinning these fibres, every thread breakage on the ring, causes a sure reeling of fibres on the drowing cylinders, it is essential that the rings are endowed with "feed-stop" devices.
The whole spinning process must be adapted with the purpose to reduce the friction between fibres and metal. The majority of high tech fibres has high longitudinal tenacity, but very poor performance to the tangential abrasions.
It must be projected spinning diagrams, with regulations of the spinning and winding machines, that have to avoid any stress at the fibres, holding well present the physical and mechanical characteristics of every fibre component the yarn.
Besides the normal parameters of control of quality of the yarns, regularity, cleaning, tenacity at breaking, elongation at breaking, thin points, tick points, neps, hairiness, etc. it is necessary to introduce, in the quality control, parameters not generally used for normal yarns:

Yarn shrinkage in hot water, vapour, hot air.
Yarn modulus at 5%, 10%, 20% of the elongation.
Microscopic inspecting of fibre abrasion.
Control of the content of micro-fly into the yarn (staff-test).

The correlation among the quality yarn data , with the data of the component fibres, (real and verified for every lot of fibre, because normally the fibre specifications have very high border of tolerance from the average value, and in many cases don't bring important values as, modulus, vapour shrinkage, etc.) allows to maintain the production under control with acceptable precision.
It must be kept in mind, that many high tech yarns, are containing conductive fibres, and some of the normal frames, used for the quality control of the yarn, both during spinning process and laboratory check , don't work at all. For instance Uster regolarimeter and capacitive clearness. Each mill has to develop internal tests using alternative testing instruments, for instance optics frames, and to correlate the obtained data with these tools, to data generally reported on yarns quality standards.

4.2 Twisting (3.0.S.)

For the already above writing high sensibility of the high performances fibres to any tangential friction, twisting of high tech yarns must be made only on D.T. twisting frames, without the ring for the control of the balloon, to avoid any friction between the fibres and the metal ring.
It is to consider that it is not very often usable lubricant in twisting, harmful for the following workships. Twisted yarns both from staple fibres and continuous filaments, normally are necessary of a thermosetting, with steam, under vacuum, at a temperature, > 100°C.

4.3 Filament Yarns (1.1.F.)

Continuous filaments, are entirely produced by few fibre producers , and, on the market point of view, limited to aramid fibres. They don't need, in the yarn textile cycle, any kind of modifications , except, very limited cases, as, joining among high tenacity filaments (para-aramid, PBO, PTFE.) with conductive filaments, (metallic filaments or of carbon).
In terms of quantities, the use of continuous filaments it is limited, both for cost reasons, and for the impossibility to optimise the final products, blending different H.T fibres.
With to day's technology it is quite impossible texturing high performance filament, also with thermoplastics polymers just like PPS. On the market there are only flat filaments.

4.4 Yarn Dyeing

Most of high tech fibres are not dyeable or very difficult to dye.
When necessary, aramid fibres are dope dyed during extrusion.
Fastness of dope dyed fibres are at top levels, both in grey and blue scale.
It is possible package dyeing some types of meta-aramid fibres, with basic cationic dyestuff at high temperature, more than 130°C, using a high percentage (>20%) of some kind of carriers, as benzil-alcool, in the dye bath. Fastness are very poor.
In the case, enough common, of flame retardant fibre and high tech fibre blended yarns, generally the high tech fibre is dope dyed, while the flame retardant fibre is normally dyed on cones.

5. FABRIC MANUFACTURING

5.1 Weaving (1.W > 1.4.W.)

5.1.1 Warping (1.1.W), Sizing (1.2.W.)

Tensions in warping must be perfectly homogeneous. A high performance fabric often has very high density. In many cases the gr/mqs 3.000 are overcome. A warp not perfect, under these conditions, becomes not processable on the loom
In case of using conductive yarns, it is necessary to avoid warping frames with electric contacts.
Are also to avoid at all, sizes and oils, not fully water soluble, or not compatible with the final end use of the manufactured article.

5.1.2 Loom Weaving (1.3.W.)

It is possible to weave with any type of loom, provided that has the proper characteristics for the typology of the fabric that it is had to produce. (fabric very light, very heavy, by spun yarns, by continuous filaments or both, etc.
Type of fabrics, produced with very rigid or slippery yarns, need to be woven on rapier looms with positive rapier.
Also in weaving, in case of using conductive yarns, it is necessary to eliminate any electric contact.
The formation of folds on the fabric roll of the loom, it is very dangerous, because of, it is really hard to eliminate them in finishing.
A computer control of the weaving process, type Uster Loomdata, it is to consider essential.

5.1.3 Row Fabric Inspecting (1.4.W.)

It can seem banal this paragraph, because this operation is always performed also in the textile cycles of commodities textile products.
In the case high tech fabrics production, it has also to serve as process control, for immediate interventions to eliminate possible faults, and it is performed, both directly on the looms, opportunely equipped with its own observatory , and into the control department.

5.1.4 Finishing – Dyeing (2.W > 2.3.W.)

Only in little cases high performance fabrics are piece dyed . Fabrics based on meta-aramid fibres and blends with fr fibres, are in few piece dyed, on overflow or jigger, under pressure, with the same formalities of yarn dyeing.
Finishing is instead very important, to reach the requisite of many final products.
Desizing and scouring have to be performed in perfect way. Small traces of size or oil on the fabrics, can compromise the performances of the final product.
Thermosetting is normally make at extreme conditions, in terms of level of temperature and time of treatment..
Some high tech fibres, don't lose their primary characteristics, as fire protection and heat resistance, even if the fabrics are submitted to particular treatments of finishing, as anti-crease, water-repellent, anti-bacteria, etc. In these cases it is necessary to select finishing products compatible with the characteristics of the used fibres.

5.2 Knitting (1.K.)

5.2.1 Warping (1.1.K), Warp knitting (1.2.K.)

The manufacture of beams it is requested only for warp knitting. Are used, only continuous filaments, mainly of flame retardant fibres, PES fr.
There are also some fabrics of aramid continuous filament, mainly used by backing for coating. The produced quantities are marginal. Treating of knits produced by filament, the technical ties, are only connected at possible electrostatic charge.

5.2.2 Circular Knitting (1.3.K.)

Single jersey and interlock knitted fabrics for protective underwear are mainly produced by spun yarns of aramid fibres, pure or blended with viscous fr,.
It is possible to use any type of knitting machine. In the case, enough common, of fabrics made by single yarns, it is often necessary, to give stability to finished knit fabric, to use yarns with opposite twist, S+Z. In case of using conductive yarns, it is necessary to avoid any electric contact.

5.2.3 Row Fabrics Inspecting (1.4.K.)

It is quite impossible to inspect knitted fabrics directly on the knitting machine. To avoid mistakes, the control department, has to work just in time with the production department, to hold under control the manufacturing process.

5.2.4 Finishing – Dyeing (2.K> 2.2.K.)

Also knitted fabrics are only in little cases piece dyed . Fabrics based on meta-aramid fibres and blends with fr fibres are in few cases piece dyed, mainly in jet or overflow.
Finishing, desizing and scouring have to be performed at the some condition before written for woven fabrics.
Application of softener products if necessary, must have done with a lot of caution, how it can damage the performances of the ended product.

REFERENCES

BISFA, The International Bureau for the Standardisation of Man-Made Fibres – Terminology of man-made fibres, 2000 Edition.

Pio Bertoli, Manuale delle fibre tessili, Etas/Kompass.

Hans J. Koslowky, Chemie Faser Lexicon: Begriffe, Zahlen Handelsnamen, Deustcher Fachverlang 1997.

Prof. Kirikk E. Perepelkin, St. Petersburg State University of Technology, Russia, Dr. Nikolai N. Machalaba, J-S Co "Tverchimvolokno" Twer, Russia – Para-aramide "World-family"; Comparison and modification possibilities for different applications.

Antonino Piccolini, Centro Tessile Cotoniero ed Abbigliamento, Busto A. Italy, Fibre High Tech e Flame Retardant, 1997.

TUT, Institut Textile de France. Characteristics Man Made Fibres for technical end uses.

BASF Aktiengesellschft, Marketing Industrial Fibres, Ludwigshafen, Germany. Basofil, heat & flame resistant fibre.

Du Pont, Geneve, Swiss, Engineering Fiber System, 1995.

Kermel Rhodia, Colmar, France. Kermel® High-Tech thermostable and non-flammable fibre.

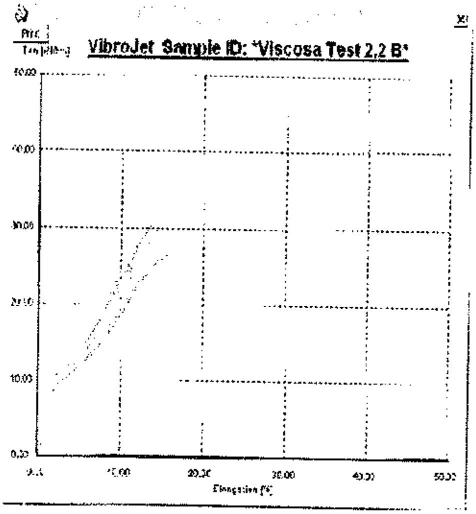
Teijin Limited, Technora Department, Osaka, Japan. High Tenacity Aramid Fibre Technora®, Technical Information 94.4.

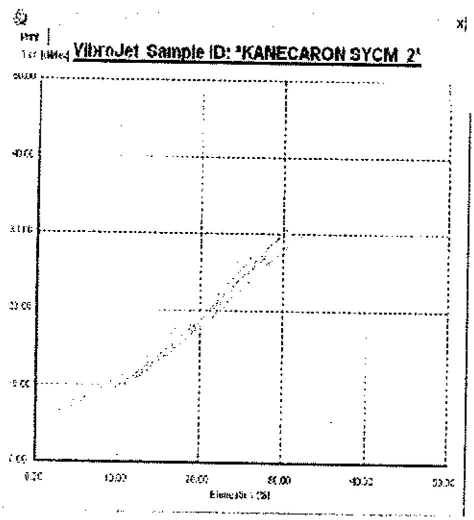
Teijin Limited, TeijinConex Department, Osaka, Japan. TeijinConex Flame & Heat resistent Meta Aramid Fibre ®, Technical Information 96.12.

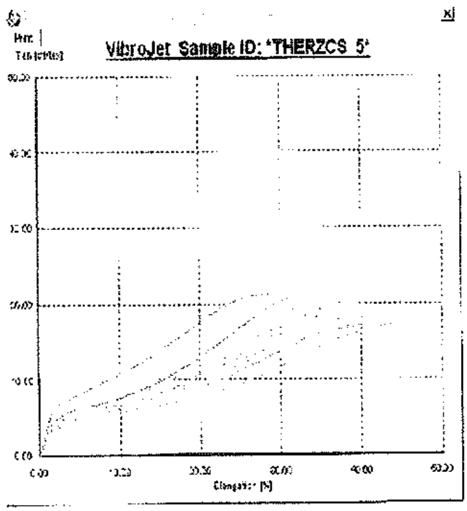
Teijin Twaron BV, Arnhem, Holland. Twaron news, 1997, 1998, 1999, 2000, 2001, 2002.

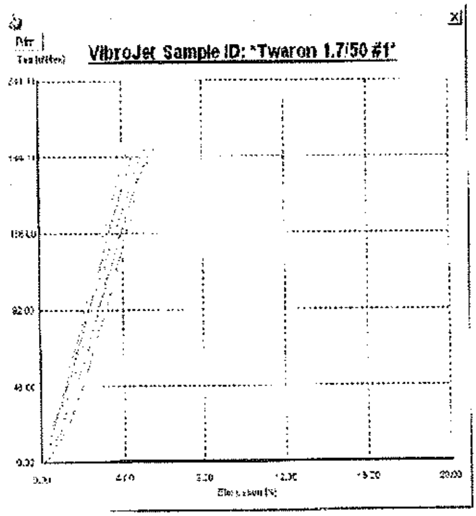
Toyobo Co. LTD, Osaka, Japan, Zylon Department, Osaka Japan, Zylon Technical Information.

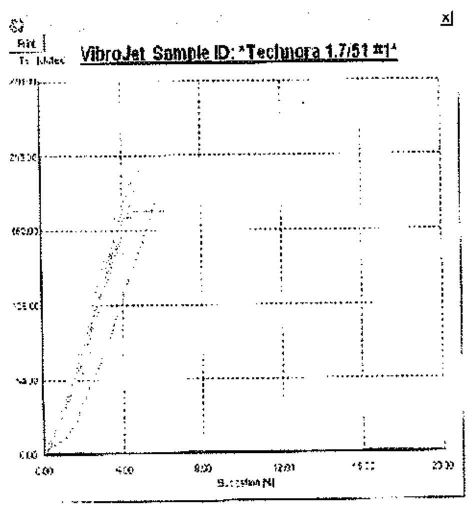
Toray Industries Inc. Industrial Materials Dept., Osaka Japan, PPS Fiber Torcon

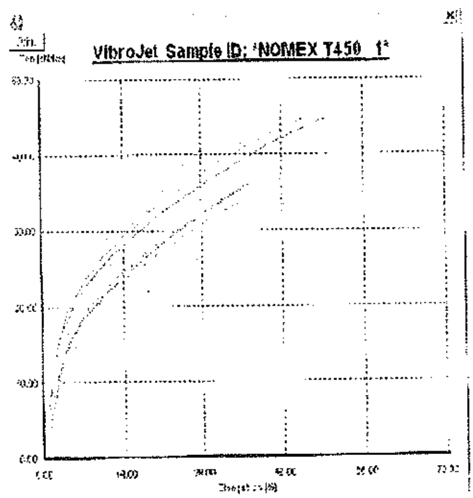


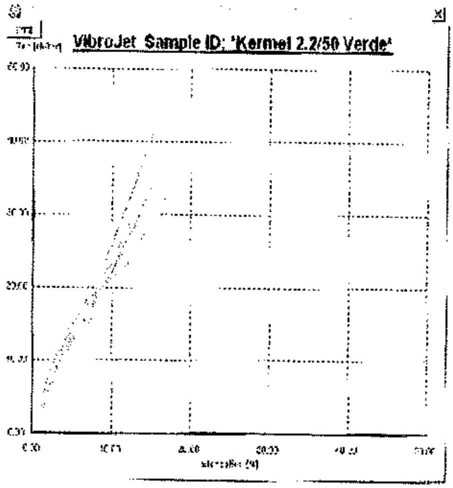


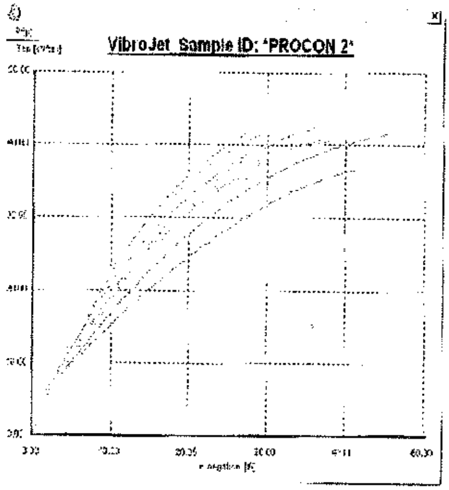

VibroJet Sample ID: "THERZCS 5"

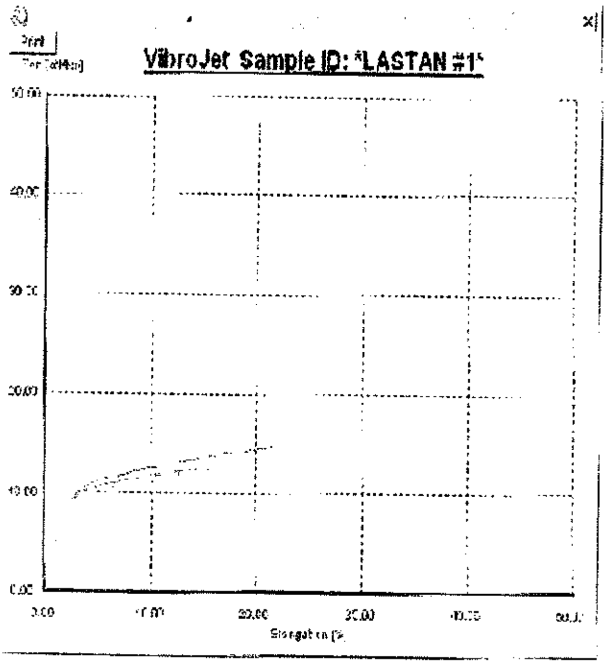

VibroJet Sample ID: "Twaron 1.7/50 #1"


VibroJet Sample ID: "Technora 1.7/51 #1"


VibroJet Sample ID: 'NOMEX T450 1"


VibroJet Sample ID: 'Kermel 2.2/50 Verde'


VibroJet Sample ID: 'PROCON 2'


VibroJet Sample ID: 'LASTAN #1'
50.00
40.00
20.00
10.00
0.00
20.00
30.00

PRODUCTION OF WARP-KNITTED TECHNICAL TEXTILES ON WEFT-INSERTION MACHINES WITH REFERENCE TO PRACTICAL EXAMPLES

C. Iyer
CText FTI, Fachhochschule Reutlingen,
University of Applied Sciences, Germany

1. INTRODUCTION

Technical textiles include all products which do not fall into the classical definition of outer- and underwear, home or decorative textiles and exclude a newly emerging group of textiles, often being referred to as „intelligent textiles". The significance of technical textiles has been steadily increasing in the last decades. The production of home-based textile products in this field is already more than 50% in countries like the U.S.A. and Japan and around 40% in Western Europe.

Textile Products for Technical Application

Although no specific statistics are available, a world-wide breakdown of textile products today for technical application could be roughly estimated as follows:

non-wovens:	≈	40%	(slowly increasing)
woven articles:	≈	35%	(stagnating)
knitted articles:	≈	16%	(increasing)
rest:	≈	9%	(braids, ropes, cables, etc.)

It can be seen that there is considerable scope for increasing the use of knitted articles. One of the main reasons for the low percentage value here is the fact that woven items were traditionally in use for non-clothing articles. The introduction of knitted fabrics in the technical field is relatively young and just over a period of about 25 years. Potential users had problems associating knitted articles with technical application. At the beginning, they never thought of considering a knitted structure for such a purpose. And the producers of knits were neither in a position to specify and market specific properties and advantages of knitted structures, nor did they have machines and technology for the construction of these structures.

Dominance of Warp Knits within Knitted Structures for Technical Application

Within the field of knitted structures used in the area of technical application, it can be estimated that warp knits have a percentage volume of around 85%. The remaining 15% are divided between flat and circular weft knitted articles. There are several reasons for this dominance of warp knits.

Loop Structures

Weft knitted loop structures are made out of 100% **open loops**. The connection between the loops leads to a structure, which basically has a high degree of extension and elasticity in the horizontal direction. This property certainly can be used to advantage in specific applications, but they are relatively limited in use. Warp knitted loop structures (100% loops) can be made with **open or closed loops**. The connection between the loops here offers a greater variation with regard to extension, elasticity and strength in the one or the other fabric direction.

Inlaid Yarns

One of the big advantages, especially in connection with **plain warp knits**, lies in the fact that it is possible to design and construct structures **with inlaid yarns**. This is also possible with weft knitted structures, but only to a very limited extent. Basically the inlaid yarns do not form loops, and have to be held together by at least one set of loop-forming yarns.

The inlaid yarns selected for reference in this paper are the following:
Horizontal Weft Yarn
Diagonal Weft Yarn
Warp Yarn
These yarns are laid in a completely „stretched" yarn state in the fabric. The configurations of a horizontal weft yarn in a warp knit and an intertwined weft yarn in a woven structure (plain weave) are shown in Fig. 1.

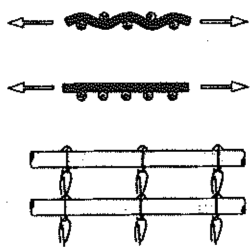


Fig 1. Bent weft yarn in woven structure
Straight weft yarn in warp knit
Weft yarn held by pillar stitches in warp knit

Axial Orientation of Warp Knitted Structures

Warp knitted structures are described as axially or directionally oriented, when they contain such inlaid yarns in a preferred axis , or in more than one axis in the surface, depending on the use they are put to (Fig. 2).

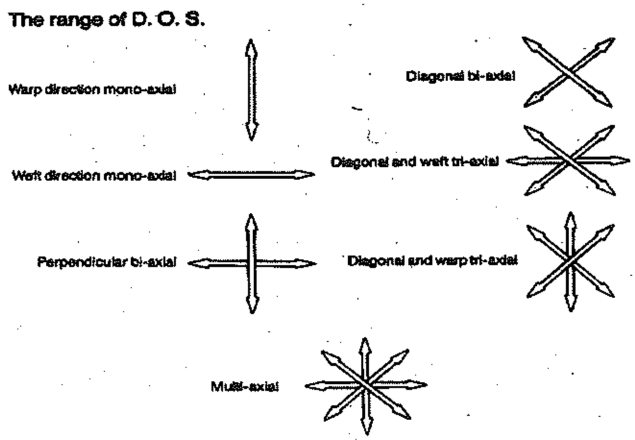


Fig 2. Directionally oriented warp knits with inlaid yarns

Since these inlaid yarns do not form loops it is literally possible to process any type of yarn (e.g. low-twist staple fibre yarns, high tenacity polymer filaments, carbon, glass).

Directional orientation is utilised to enhance or improve specific mechanical fabric properties in the axis direction like strength, modulus, dimensional stability, extension, elasticity, load distribution as well as resistance to tear and fatigue.

Warp Knit Textile Composites

The term „reinforced textile composite“ is generally used to describe a material in which a textile product (usually a monoaxial yarn prepreg, a woven, knitted or braided textile fabric) is entirely enclosed by a duroplastic or thermoplastic substance during a suitable aftertreatment.

As against this, the term „textile composite“ is used here to denote the following:
Yarn reinforced fleeces
Yarn reinforced chopped fibres (usually glass)
In both these cases the initial reinforcement is achieved with the help of inlaid yarns and yarn loops. If necessary, such a product can also be further treated to produce a reinforced textile composite. The production of such **textile composites in one process** is a speciality of warp knitting.
The construction of directionally oriented structures and textile composites will be illustrated here, taking the examples of machines made by the company LIBA Maschinenfabrik GmbH, Naila, Germany.

The Machine Copcentra HS 2 for Weft Insertion

This is the standard tricot machine, equipped with the horizontal weft insertion system **HS**.
On the back side of the machine, weft yarns are withdrawn from creels, carrying upto 30 cones. With the help of a weft carrier the yarns are laid horizontally (and parallel to one another) around hooks, which are attached to transport chains at both ends. The process is continuous. With the help of clamps the yarn position is fixed at the hook (Fig. 3). This guarantees a constant and optimal weft yarn tension. The weft yarns in this configuration are transported forward and laid into the knitting zone.

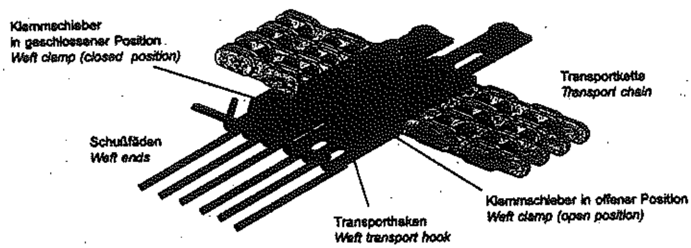


Fig 3. Weft Clamping System on Copcentra HS 2 machine

The electronic weft yarn carrier drive **EMS** with servo motors leads to a very high weft insertion speed. The carrier can be equipped for either 30 yarns at a pitch of 1/3" or 24 yarns at a pitch of 1/2". Also the mechanical camdisc drives have been replaced by electronic controls (**ERS**) for the shogging rake of the weft carrier. They permit faster and easier adjustments and changes for different working widths.

With the help of this machine mono-axial structures with horizontal weft yarns can be produced. Although a larger percentage of articles produced today are for apparels, the machine is being increasingly used for the construction of structures containing technical yarns in the weft like e.g. glass or high tenacity polyester filaments. It is basically possible to use weft yarns of different types and counts at the same time.

The Machine Copcentra HS 2-ST for Perpendicular Yarn Insertion

The standard machine HS 2 can be converted into the version HS 2-ST for the construction of biaxially oriented fabrics, using inlaid horizontal weft yarns and perpendicular warp yarns (pillar threads).

The geometry of the knitting elements (Fig. 4) permits a completely linear pillar thread presentation into the knitting zone and into the fabric. This means that the pillar threads can be processed at high yarn tensions. Pillar thread guide sinkers lead to an exact positioning of each thread in such a way, that they never come in contact with the knitting needles. The strain on the pillar threads is thus considerably reduced. The guide sinker bar for the pillar threads can be rigid or move laterally as required.

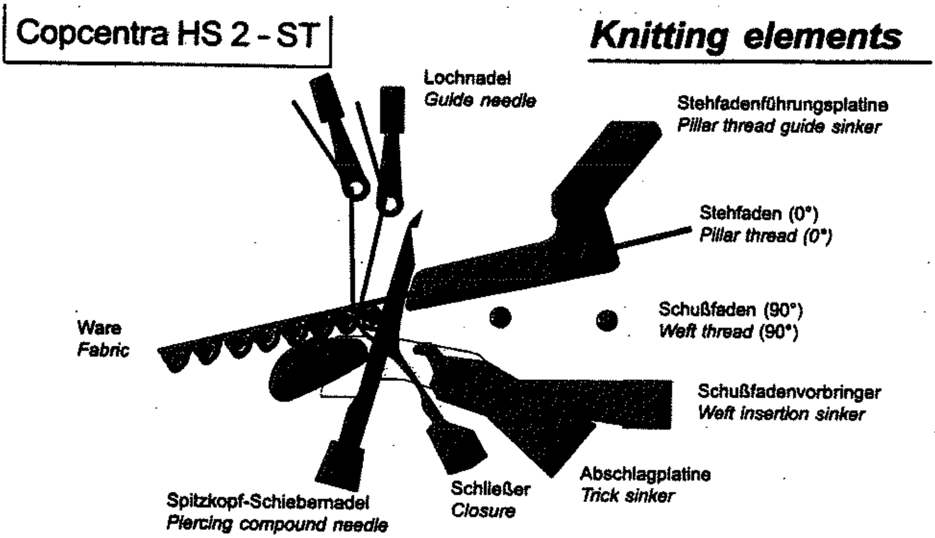


Fig 4. Pillar thread insertion on Copcentra HS 2-ST machine

The fabric can be taken-off from the knitting zone in two different angles.
Tricot Take-off: The take-off angle here is almost horizontal. The pillar threads move horizontally through the guide sinkers and are also taken-off in the same direction, leading to a reduced yarn strain, as in the case while producing fabrics for awnings or geogrids.
Raschel Take-off: The take-off angle here is almost vertically downwards. This is only used when two pillar thread systems are worked into the fabric to obtain a weave structure imitation. The pillar threads are guided by standard guides on a guide bar (machine variation: Copcentra HS 3-ST) and are taken-off downwards, without bending them.

This machine is available in a gauge range of 6 – 24 needles/inch with working widths between 160" – 245" (406 – 622 cm). Knitting elements include 2 guide bars, e.g., for loop formation and compound needles. With 5 rows/cm it has a production speed of 1500 rows/min or 180 m/h. This speed is specifically 200 m/h for a fabric width of 50" and 130 m/h for a width of 100".

Examples of Fabric Application

In a warp knitted fabric containing more than one layer of linear inlaid yarns the **yarns between the layers are not intertwined** with one another. This means that mechanical yarn properties straining the fibre substance can be fully exploited in each axial direction.
One example in comparison with woven structures is the much higher tear propagation resistance of perpendicular biaxial warp knits. This is because the inlaid yarn layers initially tend to bunch together under load when a tear occurs. A higher force is thus required to prolong the rupture (Fig. 5).

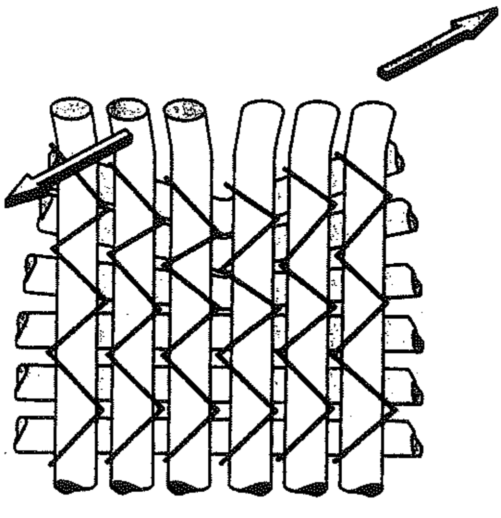


Fig 5. Bunching phenomenon of inlaid yarns under rupture in a warp knit

Most of the fabrics with biaxially perpendicular inlaid yarns are laminated and coated. Laminated substrates with relatively closed structures are used, e.g. for advertising sheets (billboards), backlites, tarpaulins (trucks), awnings, sun shades, camping and deck chairs and as carrier and reinforcement fabrics.
Coated fabrics with larger openings are being used successfully as geo-grids in road and building construction or for stabilising slopes. They are also used, e.g. as safety nets in station wagons (to separate luggage from back-seat passengers).

The Machine Copcentra HS-2-ST-CH with Fibre Chopper

The attachment CH is used for the online preparation and presentation of chopped fibres (here: glass) to the knitting zone. Glass yarns or rovings are withdrawn from cylindrical yarn packages, placed across the working width of the final fabric and are continually chopped with the help of cutting rollers. The chopped fibres fall onto a conveyor belt in the form of a mat. The belt transports the mat directly into the knitting zone (Fig. 6).

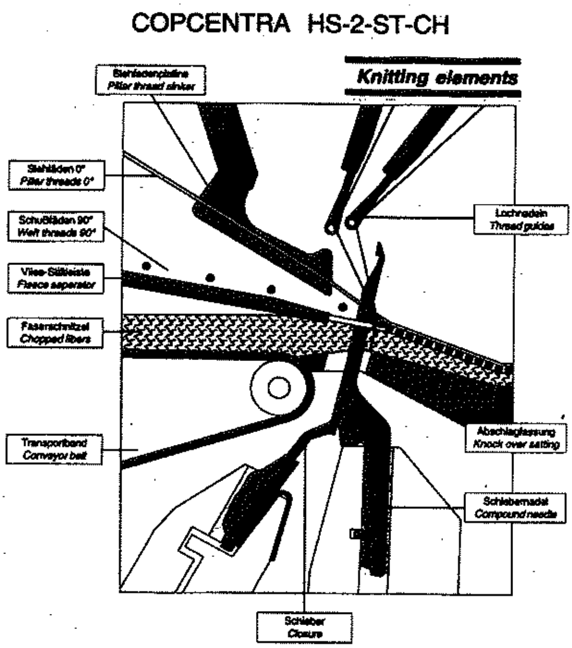


Fig 6. Chopper fibre feed in knitting zone of Copcentra HS 2-ST-CH machine

The geometry here is such that the following layers are built from top to bottom:

Pillar Threads (Warp Yarns)
Horizontal Weft Yarns
Chopped Fibre Mat

The heads of the compound needles have a pointed construction to pierce through the fibre mat in order to take up the loop yarns which hold all the three layers together.

Fig. 7 shows two sides of a textile composite with chopper fibres.

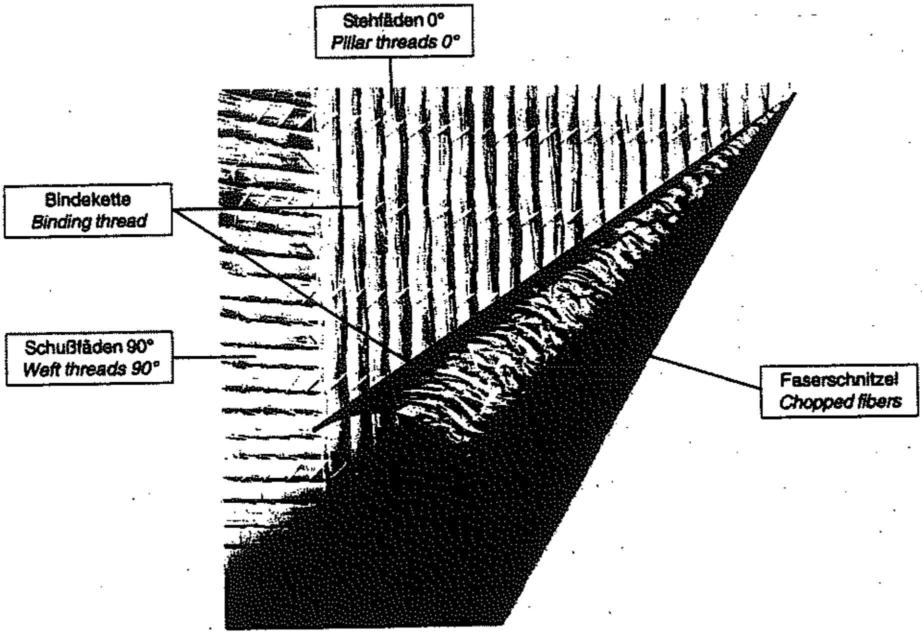


Fig 7. Warp knit textile composite with chopper fibres, pillar threads, horizontal weft and binding loop yarns

During the vertical motion the needles move sidewards additionally (in the direction of fabric movement). This is a new development, called „Walking Needle Concept" and has the following advantages:
Reduced pressure from chopper fibres = Less wear on needles
Smaller punctured holes = Better textile composite fabric quality
Reduced needle/fibre friction = Higher production speed

This machine is available in the gauges **E5, E6, E7 and E10** (needles/inch). The chopping device has motor-driven diamond-disc blades and 2 separately arranged vacuum units. The chopped fibre length is 50 mm or 100 mm. The machine is offered for working widths of 108" (275 cm) and 130" (330 cm). It has a performance, e.g., of 1000 rows/min or 150 m/h with a fabric density of 4 rows/cm.

Examples of Fabric Application

All the fabrics produced with biaxial yarns and chopped fibres undergo further treatment for obtaining textile reinforced composites. Chopper fibres bring in more volume and lead to a smoother, unstructured fabric surface. Since multiaxial fabrics are also used for textile reinforced composites, details given in the next chapter also hold good for such articles.

The Machine Copcentra MAX 3 CNC for Multiaxial Warp Knits

This is the most successful machine type on the market today. The multiaxial machine enables – amongst other things – the preparation and presentation of **inlaid diagonal weft yarns**. In its basic version (Fig. 8) it is offered with three weft insertion systems (or stations). The sketch also includes the following: equipment for pillar threads (warp yarns) and fleece delivery (beneath the frame and behind the knitting zone). The sketch also shows yarns (the 1st set to the right) and the cutting device for chopper fibres (before the 1st weft insertion system), offered as an option. The basic version can be extended by up to 4 further weft insertion systems. Fleece can also be delivered additionally from the top.

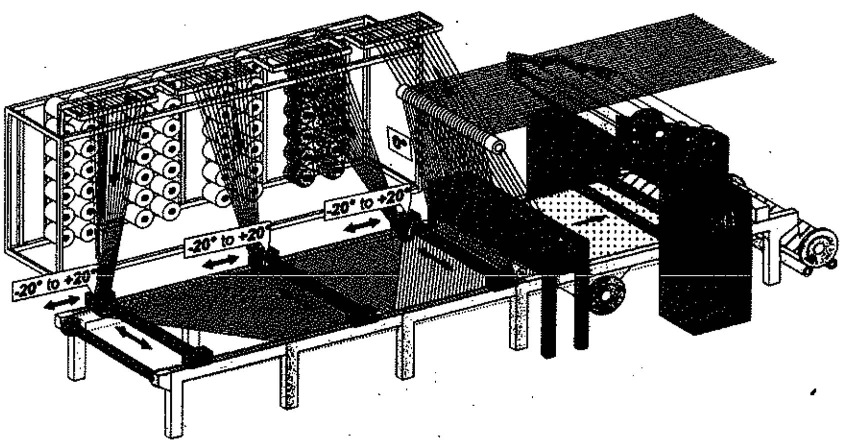


Fig 8. Basic version of Copcentra MAX 3 CNC multiaxial machine

At each weft insertion system the diagonal angle can be set independently. Settings between –20° - +20° are programmed directly at the terminal. A standard frame length of 8 m is sufficient for using two 45° and one 90° (horizontal) weft insertions. It is extendable, e.g., for using three 20° diagonal weft insertions.

An example in Fig. 9 shows five inlaid yarn layers, consisting of 2 diagonal weft layers (± 45°), 2 horizontal weft layers (90°) and one warp yarn layer (0°).

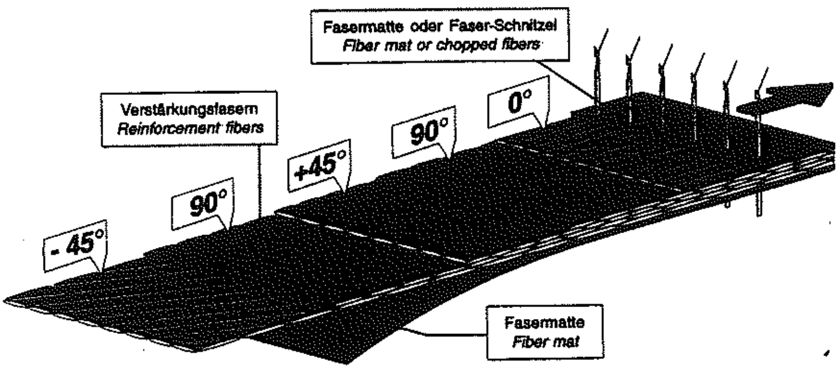


Fig 9. Example of multiaxial warp knit textile composite fabric construction

Chopped fibres, fibre mats (fleeces) and/or other materials can be included on the outer surface or – if desired – inbetween the single layers. This reinforcement complex is then held together by a loop yarn system.

The machine is equipped with two loop yarn guide bars and a pillar thread bar, which can be rigid or laterally moveable. It is offered in the gauge range E3 – E12 (needles/inch) with a working width of 50" (127 cm). The standard gauge of the weft insertion reeds is E12, and the max. band width for weft yarns is 4".

Also on this machine it is possbile to use all types of yarns as inlaid material. In practice, however, mainly filament yarns are used, containing polyester (also high tenacity), polyethylene (high modulus, high density), polyamide, glass and carbon. It is always possible to have different materials in or within one layer.
The loop yarns have only the secondary role of fixing the positions of the inlaid yarn layers. Therefore standard yarns, mostly filaments, are used for this purpose.

What is a Multiaxial Fabric ?

It is first of all important to note that it is possible to obtain a „multiaxial" reinforcement structure in various ways for direct use or for further treatment:
Woven Fabric: Layers of woven fabrics are laid one upon the other with yarns in different angles, and bonded together.
Multi-Stitched Fabric: Fabrics with yarns at different angles are stitched together adjacently and laid one upon the other.
Cross-Weft Fabric: The inlaid yarn sections from one traverse to the next (of the weft yarn carrier) show deviations from the requiered or specified angle. For example, the prescribed angle for horizontal weft yarns is 90°. Actually the angle deviation lies approximately in the range ± 85°. This happens, e.g., with stitch bonding multiaxial machines, not additionally equipped with a 90° weft insertion.
This is the main reason why the firm LIBA has patented products made on the machine (described above) under the trade mark PARAMAX.

Examples of Fabric Application

All multiaxial fabrics, as well as textile composite fabrics (reinforced fleeces) with biaxially perpendicular inlaid yarns undergo further treatment for obtaining **textile reinforced composites**. Either as plates or as pre-shaped moulded components, such composites compete successfully with other products in a very wide range of application. Just a few examples are given below:
Bodies and hulls of sports boots, jachts and omnibusses
Blades for boat paddles, helicopter and wind energy rotors
Ski equipment
Components in automobiles, motor-cycles and planes
Containers (cargo ships and waste disposal)
Satellite dishes for TV programmes
Street telephone cells
Supporting and construction girders

Besides the obvious advantage of reduced weight in comparison with traditional materials used in the examples given above, composites reinforced with multiaxial fabrics, made on the machine described earlier, have some very good properties as compared with other textiles used in multiaxial form. Some of the important ones are mentioned below:
Highest specific strength

Improved tensile strength at equal weight (30 – 100%)
Reduced material costs for the same strength (around 7%)
Better fibre/matrix ratios (comparatively less resin is required)
Improved interlaminar strength / reduced delamination risks

Final Remarks

This paper has attempted to illustrate the significance of warp knits within the area of knitted textiles in the context of technical application. Special emphasis has been placed on the description of fabrics with axially oriented inlaid yarns as well as reinforced fleeces or chopped fibres. Details of weft insertion have been given, using the examples of specific machines. As in other areas these articles have to exist in the field of technical application in constant competition with other textile products like woven items and non-wovens.

The author would like to thank the firm LIBA for giving assistance in presenting this paper.

Consulted Literature

Liba	Brochures on weft insertion machines
K. Mayer	Brochure on „Directionally Oriented Structures“
Iyer, C.	Short-term lectures on „Warp Knits for Technical Application“ at the Northwest Institute of Science & Technology, Xi'an, China and at Donghua University, Shanghai, China, April/May 2002

THE MECHANICAL PROPERTIES OF WEFT-KNITTED FABRICS FOR COMPOSITE MATERIALS REINFORCEMENT

M. de Araújo, H. Hong and R. Fangueiro
Department of Textile Engineering, School of Engineering
The University of Minho, 4800 Guimarães, Portugal

ABSTRACT

Weft-knitting is the most suitable technique for the production of 3D fabrics for complex shape composite reinforcements. However, due to the loop formation, weft-knitted preforms exhibit poor mechanical properties, which limit their range of application into areas where resistance to impact is the dominant feature. This paper discusses ways in which stiffness could be improved and describes the experimental work done at The University of Minho regarding the improvement of the mechanical properties of composite materials reinforced by weft-knitted glass fabrics. The effects of the fiber orientation are analysed by comparing the tensile testing results obtained for different glass weft-knitted structures, i.e., single jersey, 1x1 jersey and fleece. These weft-knitted structures have been used in the reinforcement of a poliéster resin matrix. The composite materials thus obtained have been tested in order to analyse the effects of four different factors on the tensile properties: testing direction (courses or wales), number of layers (1 or 2), type of structure (jersey, 1x1 jersey and fleece) and pre-tensioning of the weft-knitted fabric structure (0% or 20%). The testing results are presented and the effects of each factor in the tensile behaviour of composite materials reinforced by weft-knitted structures are discussed.

1. INTRODUCTION

The application of fibrous materials in the reinforcement of matrixes made from polymers is a very interesting development both from the research and manufacturing points of view. The importance of these materials, known as composites, is becoming ever more important in the replacement of monolithic materials such as metals. In this case, composite materials present various advantages such as high specific mechanical properties, due to their low weight and good heat and corrosion resistance. The use of shaped reinforcements with the final material's geometry (preforms), is important in many ways such as waste reduction, diminishing labour costs, improving the homogeneity of the material's properties and automation of the manufacturing process [1].

All major types of textile technologies can be used to produce shaped preforms, each presenting specific advantages and disadvantages. The production of preforms using weaving technology requires the conventional process to be modified, in order to allow a yarn configuration according to the shape required. Weaving may be used for the production of multilayer fabrics with different configurations, hollow shaped fabrics and integral profiles (T, Y, and I). The complexity of the systems involved, the low productivity and the limitation of the preforms geometry are restricting the use of this technology in mass produced preforms. Braiding technologies are mainly suitable for the production of tubular preforms with a single layer. 3D braiding offers the advantages of high formability, superior mechanical behaviour, near-to-shape accuracy and low production costs [2]. The weft-knitting technology is the most versatile textile technology for the production of shaped preforms.

The use of weft-knitted fabrics in composite reinforcements is limited, due to their poor stiffness. The tensile behaviour of weft-knitted fabrics is strongly influenced by their loop structure. On the application of a tensile load, loops change their shape in order to accommodate the applied load. In the initial part of the deformation, small loads lead to large deformations, which typifies the behaviour of low stiffness materials. However, due to this behaviour, knitted fabrics are particular suitable for applications where resistance to impact and absorption of energy are the main requirements.

2. TENSILE PROPERTIES OF WEFT-KNITTED GLASS FIBER FABRICS

2.1 Testing Plan

In order to study the properties of knitted glass fibre fabrics, for application in the production of complex shaped preforms, four different structures were selected:

- single jersey,
- 1x1 jersey,
- fleece,
- sandwich connected by yarns.

Testing of these structures was conducted so as to study the influence of fibre orientation in the coursewise direction, in the mechanical performance of these fabrics. Table I presents the dimensional properties of these structures.

Table 1. Dimensional properties of the knitted structures selected

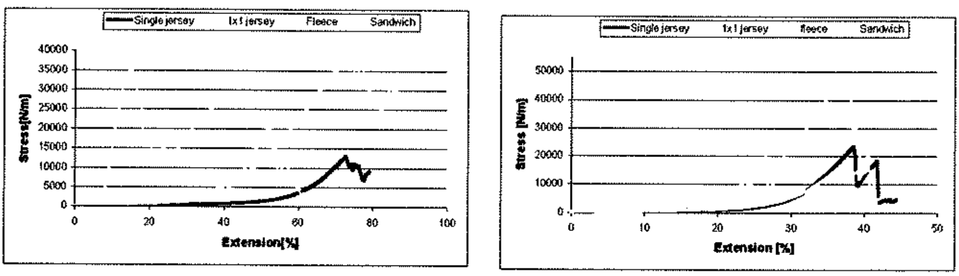
	Single jersey	1x1 Jersey	Fleece	Sandwich
Mass (g/m^2)	1100	1300	1350	3500
Loop length (cm)	0.925	1.97	2.72	0.836 and 0.724
Tightness factor	21.8	20.5	26.1	24.2
Courses/cm	6.4	3.2	2.5	4.15
Wales/cm	5.3	2.9	1.6	1.78
C/W (loop shape factor)	1.21	1.10	1.56	2.33

2.2 Testing Results

In order to study the tensile properties of the knitted fabrics presented above, testing was conducted both in the coursewise and walewise directions. Ten samples of each structure have been prepared and tested in each direction, in a HOUSFIELD H10KS universal tensile tester. The results obtained are presented in Table II, while the corresponding load-extension curves are shown in Fig. 1.

Table 2. Tensile properties of the knitted fabrics selected

Structure	Direction	Tensile strength [N/m]	Extension to rupture [%]
SINGLE JERSEY	Wales	22080	37.98
	Courses	12630	71.88
1x1 JERSEY	Wales	22386	28.14
	Courses	19627	52.31
FLEECE	Wales	18568	37.07
	Courses	38007	16.36
SANDWICH	Wales	44460	38.46
	Courses	37680	68.99



(Walewise direction) (Coursewise direction)

Figure 1 – Load-extension curves for each knitted structure tested

2.3 Results Analysis And Discussion

Analysing Table II and Figure 1 it is possible to conclude that:

- the initial modulus of weft-knitted fabrics is extremely low;
- the introduction of non-knitting yarns (fleece) increases significantly the breaking load of weft-knitted fabrics;
- the introduction of non-knitting yarns decreases significantly the breaking extension of weft-knitted fabrics;
- the introduction of non-knitting yarns in the coursewise direction does not affect the tensile properties in the walewise direction;
- the non-linear initial part of the load-extension curve, which is responsible for the low modulus of weft-knitted structures, may be modified by the introduction of non-knitting yarns, thus increasing stiffness;
- the introduction of directional non-knitting yarns enables the control of fabric anisotropy.

Furthermore, by analysing the load-extension curves, it can be seen that the knitting yarn starts to become under load after an excessively high extension, which could be a drawback for applications in composite materials. A strategy proposed to overcome or minimize this problem is pre-tensioning of the knitted fabrics before resin impregnation. The values of the pre-tension to apply in each case could be indicated by the load-extension curves. As an example, for the single jersey structure, a pre-tension of about 3750 N/m may be applied in order to eliminate 55% of the initial extension.

3. MECHANICAL PROPERTIES OF WEFT-KNITTED REINFORCED COMPOSITES

The weft-knitted fabrics tested before have been used in the reinforcement of a polyester unsaturated resin. The hand lay up technique was used to obtain composite materials with 30% of fibre volume fraction.

3.1 Testing Plan

In order to evaluate the influence of various factors on the tensile properties of weft-knitted reinforced composites, experimental work has been undertaken using an INSTRON universal tensile tester, according to the ASTM D638 standard, at a speed of 2mm/min, using a straingauge. The factors considered are presented in Table 3.

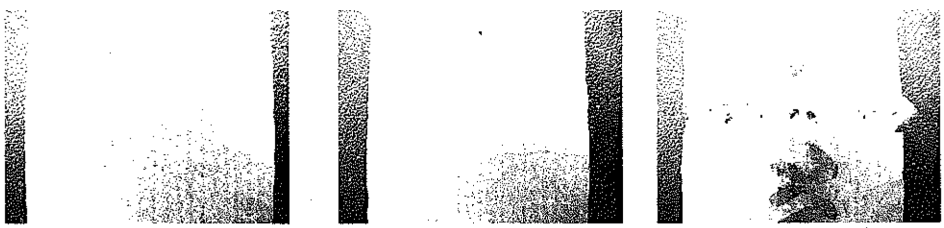
Table 3. Factors considered for the analysis

Factors	
Weft-knitted structure	single jersey / 1x1 jersey
Testing direction	Wales / Courses
Number of reinforcing layers	1 / 2
Reinforcement pre-tension level	0% / 20%

The tensile properties of composite materials reinforced by fleece and sandwich structures have also been evaluated. In the case of the fleece structure, the reinforcement has been set at an initial pre-tension level of 20% and the composite materials tested in the coursewise direction only.

3.2 Deformation Mode

Fig. 2 shows the deformation mode of a composite material reinforced by a weft-knitted fabric during an uniaxial tensile test. Fig. 2(a) shows the initial phase of the load application, where no visible alteration of the sample is apparent. At the next stage, the resin starts cracking in several points of the material, thus producing characteristic sharp sounds (Step 2). The phase after (Step 3) is characterised by the appearance of several cracks along the sample width, corresponding to resin-fiber debonding (Fig. 2(b)). Finally, fracture occurs due to rupture of the fibers providing the connection between both edges of the crack (step 4).



(a) Step 1 & 2 **(b) Step 3** **(c) Step 4**

Figure 2 – Steps in the deformation of a weft-knitted reinforced composite

Analysing a typical load extension-curve of a weft-knitted reinforced composite (Fig. 3) it can be seen that Step 1 corresponds to the initial part of the curve which is linear; Step 2, though not well defined in the curve, occurs between Step 1 and Step 3, corresponding to the part where the curve loose its linearity; Step 3 is perfectly visible in the curve due to the small oscillations which correspond to the opening of the cracks; Step 4 is illustrated by the vertical line dropping sharply at peak strength.

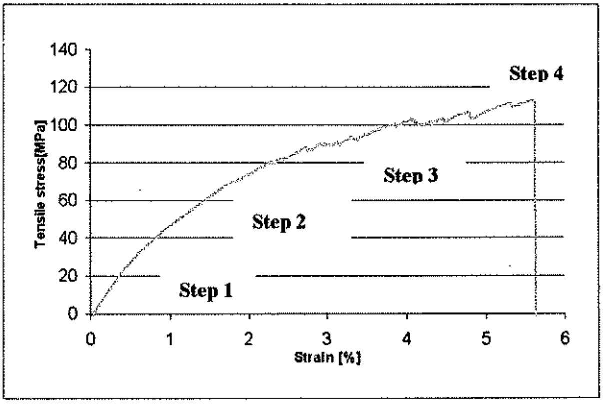


Figure 3 . Steps of deformation of a weft-knitted reinforced composite by analysing the load-extension curve

3.3 Testing Results

Tables IV, V and VI show the results obtained for maximum stress and strain and for the Young's modulus, respectively.

Table 4. Maximum strength for each composite material tested [MPa]

	Walewise direction				Coursewise direction			
	1 Layer		2 Layers		1 Layer		2 Layers	
	0%	20%	0%	20%	0%	20%	0%	20%
Jersey	85.14	100.44	76.29	108.77	24.98	35.52	28.77	36.02
1x1 Jersey	76.42	83.95	82.17	94.04	34.36	49.69	36.18	52.36
Fleece						77.93		65.22
Sandwich	36.75				25.44			

Table 5. Extension at maximum strength for each composite material tested [%]

	Walewise direction				Coursewise direction			
	1 Layer		2 Layers		1 Layer		2 Layers	
	0%	20%	0%	20%	0%	20%	0%	20%
Jersey	5.34	4.16	4.54	5.25	1.55	3.84	1.73	2.40
1x1 Jersey	4.14	5.48	5.24	5.96	1.76	2.87	1.79	3.98
Fleece						1.82		1.62
Sandwich	3.09				4.06			

Table 6. Young's modulus for each composite material tested [MPa]

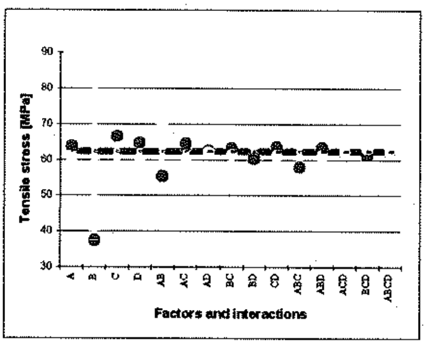
	Walewise direction				Coursewise direction			
	1 Layer		2 Layers		1 Layer		2 Layers	
	0%	20%	0%	20%	0%	20%	0%	20%
Jersey	6479.96	6562.15	4995.43	6314.53	3447.68	3811.56	3418.79	4050.13
1x1 Jersey	5690.10	6420.68	5736.64	6185.16	4089.64	5056.75	3997.77	5284.25
Fleece						7603.02		6163.84
Sandwich	4447.64				3783.01			

3.4 Results Analysis and Discussion

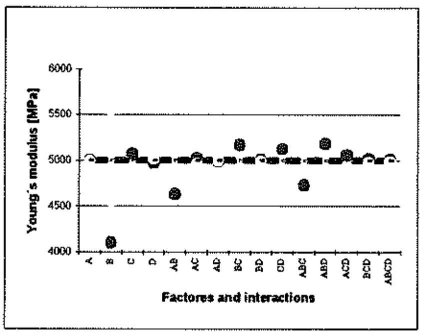
The effect of each factor selected on the tensile properties of weft-knitted reinforced composites is shown in the diagrams presented in Fig. 4. The levels of each factor in the diagrams are represented by the grey and black dots according to Table VII.

Table 7. Relationship between factors and levels

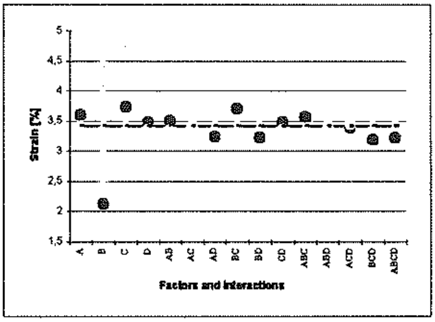
Factors	Levels	Colour
Knitted structure	1x1 jersey	Grey
	Jersey	Black
Testing direction	Wales	Grey
	Courses	Black
Pre-tension	0%	Grey
	20%	Black
Number of layers	1	Grey
	2	Black



(a)



(b)



(c)

Figure 4 . Effect of each factor on the tensile properties

(a) Effect on tensile strength (b) Effect on Young's modulus (c) Effect on extension

A - knitted structure B – testing direction C – pre-tension D – number of layers

Analysing the diagrams it is possible to conclude that:

- Tensile strength is strongly influenced by the testing direction and the level of pre-tension in the reinforcement. In this case, the best material is obtained when factors are as follows: jersey, walewise, 20%, 2 layers.
- The Young's modulus is influenced by the testing direction, the reinforcement pre-tension and, at a lower rate, by the type of knitted structure. In this case, the best material is obtained when factors are as follows: jersey, walewise, 20%, 1 layer.
- The extension at break is influenced by the testing direction, the reinforcement pre-tension and, at a lower rate, by the type of knitted structure. In this case, the best material is obtained when factors are as follows: jersey, coursewise, 0%, 1 layer.

Furthermore, in the case of the fleece structures, it is possible to use a conventional yarn in the ground structure and a high performance fiber yarn for fleece as reinforcement, without significantly decreasing the tensile performance in that direction. In order to demonstrate this, a composite material reinforced by a fleece structure with conventional polyester in the ground and glass fiber yarn in the fleece has been prepared and tested. The results are shown in Table VIII. Fig. 5 shows the load-extension curves for the composite materials reinforced by glass/glass fleece and by glass/polyester fleece.

Table 8. Tensile properties for the composite material reinforced by glass/polyester fleece

	Tensile stress [MPa]	Strain [%]	Young's modulus [MPa]
Mean	108.18	2.26	6777
Maximum	116.17	2.65	7245
Minimum	100.71	1.83	5872
Stand. deviation	7.74	0.41	490.61
C. V. [%]	7.16	18.16	7.24

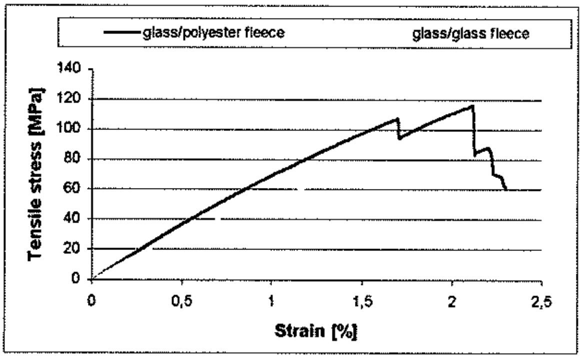


Fig. 5. Load-extension curves for the composite materials reinforced by glass/glass fleece and by glass/polyester fleece

4. CONCLUSIONS

The tensile properties of glass fiber weft-knitted fabrics have been presented and discussed. According to the results obtained, their mechanical properties can be improved by introducing non-knitting yarns into the ground structure. A comparison of the tensile results obtained for jersey and fleece structures confirm this approach.

The influence of several factors (type of structure, testing direction, reinforcement pre-tension level and number of layers) in the mechanical properties of weft-knitted reinforced composites has also been presented and discussed. According to the results, the factors with greater influence are the testing direction (wales or courses) and the reinforcement pre-tension level. Furthermore, composites reinforced with weft-knitted structures having non-knitting yarns, present the best mechanical performance. The introduction of straight non-knitting yarns and the reinforcement pre-tension seem to be effective approaches to improving the mechanical performance of these materials.

Weft-knitted preforms for composite materials may be produced using conventional fiber yarns in the ground structure, thus enabling the production of the desired shape and high performance fiber yarns as reinforcement providing strength, without loosing mechanical performance.

REFERENCES

Fangueiro, R. (2002), Optimisation of the development of weft-knitted preforms for composite materials, PhD Thesis, The University of Minho, Portugal.

Araújo, M. de, Hong, H., Fangueiro, R., Ciobanu, O., Ciobanu, L. and Moscathou, (2002), The design of complex shaped fibre based preforms for composite materials, 2nd AUTEX Conference, Belgium, 1-3 July.

DETERMINATION OF SILVER IN TECHNICAL TEXTILES USING ELECTROTHERMAL ATOMIC ABSORPTION SPECTROMETRY

B. İzgi [1], G. Akçin [2], Ş. Güçer [1]

[1] Uludag University, Science and Art Faculty, Department of Chemistry,Bursa
[2] Yıldız Technical Uni, Science and Art Faculty, Department of Chemistry,İstanbul

1. INTRODUCTION

Anti-microbial agents can be used in fibers and textiles to provide long-lasting protection against microbial growth. It is formed at the two types that are leachable and non- leachable types. Leachable type is not bounded on the fiber and can be removed by moisture. Non-leachable type is chemically bounded to the fiber. For this purpose some products such as triclosan based, silicone based, silver based is used most commonly. Anti-microbial textiles would have to obtain basic requirements such as safety for consumers (not cause allergy), no negative effects on the fiber in the process and anti-microbial efficiency durable against repeated laundering. The textile product is directly contact to human body. Humidity of the human body (sweat) is produced from the balance of human body heat from daily activities (1-3). Reagents on the fibers can be extracted by sweat and than diffuses into skin. This can be toxic to human.

Though silver is relatively non-toxic, exposure of large amounts which is produce argeria has well known toxic for human (4). In textile products, colloidal form of silver compounds is mostly used. Because of solubility balance, quantity of ionized silver on the surface is getting importance to analyze. It is known that ionic silver has high cause to precipitation of chlorides or proteins.

In this study, analytical scheme is developed for determining of silver amount on the technical textiles after using extraction techniques such as sweat, ammonia and thiosulphate (5) by ET-AAS.

2. EXPERIMENTAL

2.1 Apparatus and reagents

ATI-UNICAM 929 model atomic absorption spectrometer equipped with GF-90 graphite furnace was used for measurements. All reagents were used analytical grade. Doubly distilled water was used through all experiments.

2.2 Preparation of synthetic saliva

4.5 g. NaCl, 0.3 g. $CaCl_2$, 0.3 g. Na_2SO_4, 0.4 g. NH_4Cl, 0.3 g. $CH_3CH(OH).COOH$, 0.2 g. $H_2N.CO.NH_2$ weighed and then dissolved with small portion of distilled water and diluted 1 L with distilled water.

2.3 Preparation of synthetic acidic sweat

0.5 L-Histidine, 5.0 g. $Na_2HPO_4.2H_2O$, 5.0 g. NaCl weighed and then dissolved with small portion of distilled water and diluted 1 L with distilled water. pH is adjusted 5.5 by adding 0.1 mol L^{-1} NaOH.

2.4 Extraction procedure

After two grams of technical textile which is cut by ceramic scissors is weighed, 10 ml of synthetic saliva or synthetic sweat or thiosulphate or HNO_3 acid or ammonia solution added on the textile fibers and extracted by stirring 30 minutes in the 40 ^0C water-bath. After filtration of this solution is analyzed by ET-AAS.

3. RESULTS AND DISCUSSION

The steps to the preparation of sampling procedure is outlined in the Figure 1.

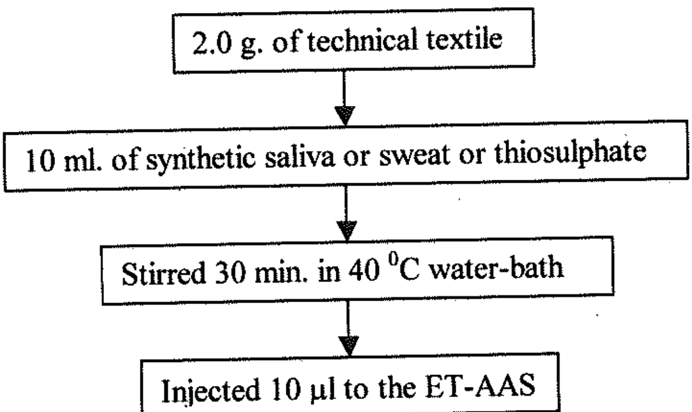


Figure 1. Sample preparation steps

Temperature profile which is prepared by 10 ng ml^{-1} of silver solution as a

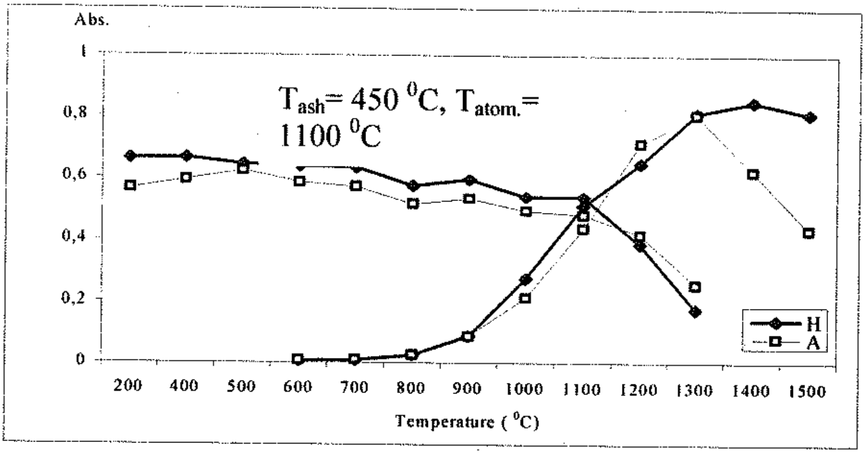
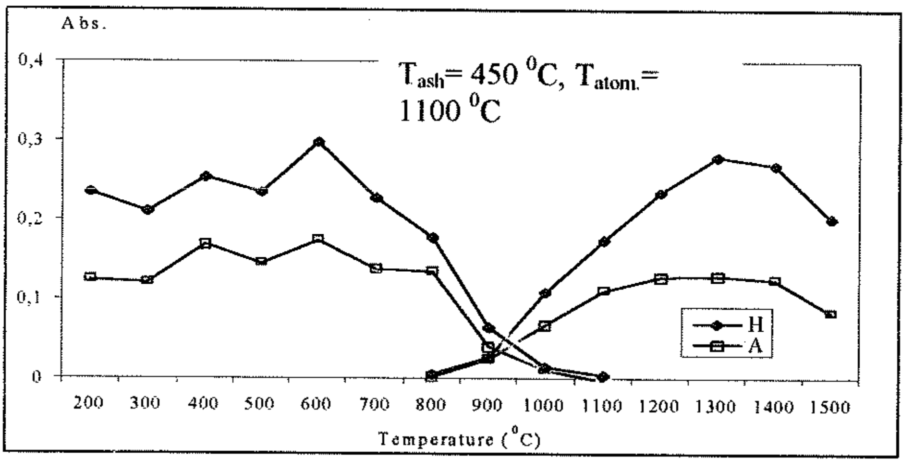


Figure 2. Temperature profile of silver without matrix modifier (H: Peak height, A: peak area)

nitrate without adding any matrix modifier is given in Figure 2

Temperature profile which is prepared by 10 ng ml^{-1} of silver solution as a nitrate adding 50 ng ml^{-1} thiosulphate as an matrix modifier is given in Figure 3.



Temperature profile which is prepared by 10 ng ml^{-1} of silver solution as a nitrate adding 50 ng ml^{-1} ammonia as an matrix modifier is given in Figure 4.

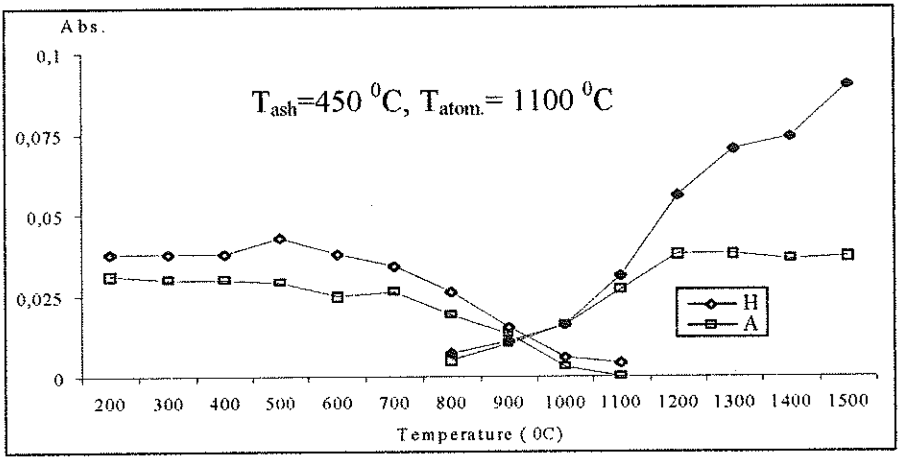


Figure 4. Temperature profile of silver with ammonia matrix modifier (H: Peak height, A: peak area)

3.1 Recovery test of silver signal

In the sample preparation procedure acid and ammonia was examined and with HNO_3 negative interference effect observed up to 70 % of recovery and with NH_3 same effect observed up to 70 % of recovery till the 5 % of ammonia solution extraction. The recovery changes on the 10 ng ml^{-1} of silver solution as a nitrate is shown for HNO_3 and NH_3 in the Figure 5.

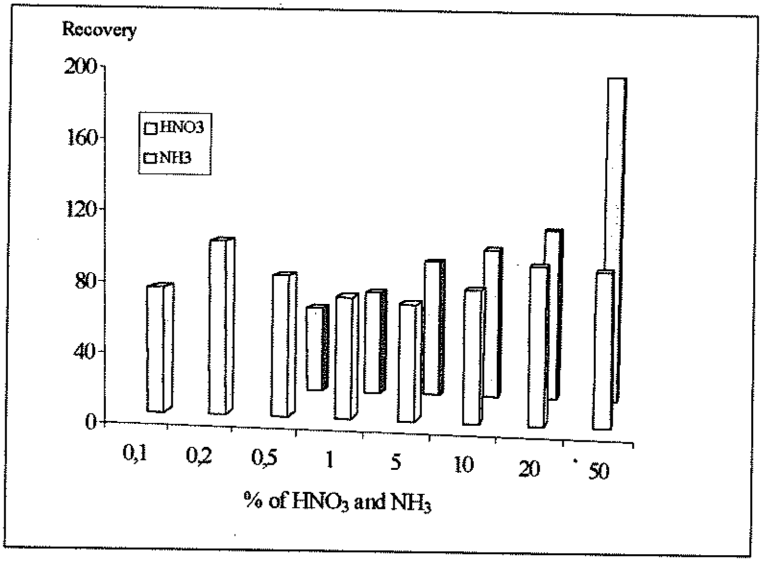


Figure 5. Effect of HNO_3 and NH_3 on the silver signal

4. CONCLUSION

The developed analytical method can be used as an important parameter for the toxic elements such as in Eco-test methods. the accuracy of results can be control using recovery tests. The analysis of silver in the textile product can also help for the understanding of preparation technology .

REFERENCES

1-Technical Textiles International, 2001,November, p. 17-22.

2-Technical Textiles International, 2001, April, p. 9-13.

3-Mansfield R. G., 2002, Tech. Text., Feb. 15 (http://www.textileindustries.com)

4- Walker A.W., 1992, SAS Trace Element Laboratories, Clinical and Analytical Handbook.

5-Rose-Janes N. G., Playle R. C., 2000, Aquatic Toxicology 51, 1-18.

DEVELOPMENTS IN DESIGN AND PERFORMANCE OF NEEDLEPUNCHED GEOTEXTILES

T.H. Shah, S.C. Anand and A. Rawal
Faculty of Technology, Bolton Institute, Bolton, BL3 5AB, UK

ABSTRACT

Geotextiles are permeable textiles that are employed to perform several functions in civil engineering applications. They can function as separators, filters, reinforcements and drainage materials. These materials are designed and produced with required strength and dimensional stability, abrasion and puncture resistance to withstand installation and application stresses to create effective and long-term solutions. The design of the fabric must fulfil the performance criteria demanded by the application. Fabric structures used in geotextiles have evolved considerably over the last few decades and today's geotextile must be adequately defined and engineered if it is to be used in any demanding civil engineering application.

In this paper the recent advances made in the design and manufacture of needlepunched nonwoven geotextiles will be discussed. The paper will highlight the results of the research on the development of empirical models based on the various factors involved in the manufacture of needlepunched geotextiles and their performance characteristics.

INTRODUCTION

Geotextiles are used in numerous civil engineering applications. They are the largest member of the geosynthetic materials family that also includes geogrids, geonets, geomembranes and geocomposites. Geotextiles can be woven, nonwoven, knitted, and knotted types. Predominantly, geotextiles are nonwoven materials, including needlepunched nonwovens and these are used mainly in subsurface drainage applications along highways, within embankments, under airfields and athletic arenas. They are also employed in critical subsurface drainage systems, soil separation, permanent-erosion control and geomembrane liners within landfills.

The structures of needlepunched fabrics are complex and the properties of these fabrics are dependent on a number of parameters such as fibre properties, web characteristics, needle parameters, process variables and the fabric finishing methods employed. Hearle and Sultan [1] showed that the needled fabric structure is directly influenced by the fibre properties, web structures and the needling parameters. They also stated that the fabric properties are mainly dependent on the type of the fabric structures developed. Purdy [2] and Lünenschloss [3] have provided a list of the important machine and needling parameters. More recently Rakshit et al [4] have studied the influence of punch density, depth of needle penetration and fabric area density on the physical properties of needlepunched nonwovens made from polyester and polypropylene fibres. These authors have developed simple relationships between the various machine parameters and the fabric properties; however, the simultaneous influence of more than one parameter has not been investigated.

The work reported here is related to the development of mathematical models using multivariate analysis of a number of important machine parameters and fabric properties involved in the design, production and application of needlepunched geotextiles.

MATERIALS

Polypropylene fibres were used for the preparation of both the industrial and experimental geotextiles. The measured physical properties of the fibres were: staple length = 100 mm; linear density = 10 dtex; tenacity = 25 cN tex^{-1}; breaking extension =100 %; and crimp = $3cm^{-1}$. The fibre type, needle characteristics and the web type were kept constant for the production of all geotextiles reported in this study.

EXPERIMENTAL WORK

Collection of Industrial Data

A large amount of data was collected from the archives of the industrial partner of the project. The data relating to the company's Medium Performance (MP) needlepunched geotextiles was summarised and used for the development of initial mathematical models. This data has been generated over a period of several years in the quality control laboratories of the company.

Design of Experiment

The experimental design was based on level 3 full factorial design and a total of twenty-seven fabrics were produced. The ranges of machine parameters employed for the production of the experimental fabrics are given in Table1.

Table 1. Process Variables Used in Production of Experimental Geotextiles

Process Variable	Value Used		
Web Area Density (gm^{-2})	400	800	1200
Punch Density (punches cm^{-2})	150	225	375
Needle Penetration (mm)	08	10	12

Production of Experimental Geotextiles

Medium Performance geotextiles were produced on a 1-metre wide laboratory needlepunching line at Bolton Institute according to the experimental design as described earlier. The cross-laid, pre-needled, polypropylene fibre web was made on a 6-metre wide industrial needlepunching line at Geofabrics Limited, Liversedge, UK. The web was used to prepare a series of twenty-seven Medium Performance geotextiles on the above laboratory machine at Bolton Institute. In order to study the influence of the main machine parameters, such as web area density (WAD), needle penetration (NP) and punch density (PD)) on the properties of the geotextiles produced, a wide range of these parameters were employed as given in Table 1. The type of fibre, needle type, needle-board design and needle-board density were kept constant for the entire series of twenty-seven experimental fabrics.

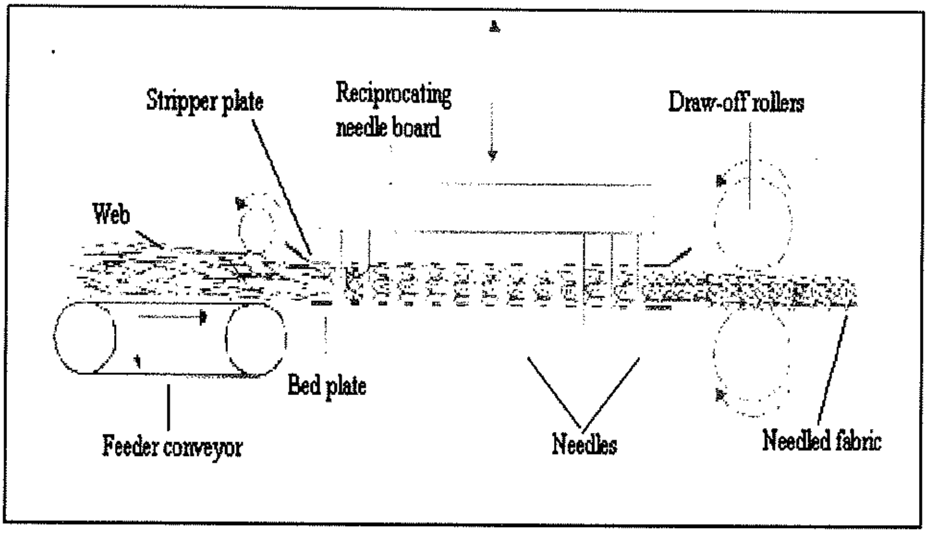


Figure 1. The Needle Punching Process

Testing of Geotextiles

A number of standard test methods were used on all the experimental geotextiles produced to determine their fabric area density (EN965, 1995), thickness (EN964-1, 1995), puncture resistance (EN ISO 12236, 1996), tensile strengths in the machine and cross machine directions (EN ISO 10319, 1996), and breaking extensions in the machine and cross machine directions (EN ISO 10319, 1996).

The results obtained from the tests carried out on the commercially manufactured Medium Performance needlepunched geotextiles were used for the development of empirical relationships between the fabric dimensional properties and the performance characteristics. The results of the tests and analysis of the experimental needlepunched fabrics produced at Bolton Institute are given in Table 2 and these were used for the development of empirical relationships between the production machine parameters and the dimensional and functional properties of the Medium Performance geotextiles.

Techniques and Tools Use for Mathematical Modelling

Multiple linear regression analysis is a technique that can explore the relationship between several variables. It is a multivariate technique and is an extension of simple linear regression analysis, which can be used to examine the effect of a single variable whilst holding the contribution of the other variables constant.

After a careful examination of the available data, it was decided to use the multiple linear regression method to develop the mathematical models to relate the machine parameters, dimensional properties and performance characteristics of the needlepunched geotextiles produced. Multiple regression analysis was carried out using the SPSS Version 8 and Maxstat software packages. Several mathematical models were developed to predict the various performance characteristics from both the dimensional properties and production process parameters of the experimental as well as commercially produced geotextile fabrics.

Table 2. Effect of Machine Parameters on Dimensional and Functional Properties of Medium Performance Geotextiles Produced on Laboratory Machine

Fabric Number	Machine Parameter			Dimensional Property/Functional Property					
	WAD	NP	PD	FAD	FBT	FBD	CBR	TMD	TXMD
1	400	08	150	505	6.80	0.074	3.52	17.30	39.30
2	400	10	150	514	5.60	0.082	3.82	19.24	35.90
3	400	12	150	470	4.83	0.084	3.71	18.70	39.90
4	400	08	225	515	6.31	0.082	4.06	20.34	36.00
5	400	10	225	508	5.05	0.091	3.78	22.76	35.51
6	400	12	225	509	4.21	0.101	3.48	22.60	36.10
7	400	08	375	452	5.55	0.081	3.38	18.71	28.28
8	400	10	375	497	4.35	0.092	4.13	22.97	30.91
9	400	12	375	545	4.30	0.125	3.40	41.30	28.40
10	800	08	150	1008	11.58	0.087	8.77	33.40	57.97
11	800	10	150	1015	8.89	0.109	8.43	35.86	67.72
12	800	12	150	1030	7.18	0.116	8.25	42.80	76.30
13	800	08	225	1150	9.67	0.120	9.78	44.25	57.61
14	800	10	225	1072	7.94	0.126	9.08	42.45	69.58
15	800	12	225	1160	6.89	0.120	7.92	50.25	68.95
16	800	08	375	1109	8.62	0.146	8.74	32.56	42.56
17	800	10	375	1153	6.45	0.153	7.59	44.35	53.47
18	800	12	375	1090	6.40	0.169	5.86	42.15	55.96
19	1200	08	150	1377	11.68	0.118	13.39	51.18	71.12
20	1200	10	150	1660	10.40	0.164	14.51	62.13	102.58
21	1200	12	150	1600	11.50	0.145	12.87	58.30	105.37
22	1200	08	225	1686	10.26	0147	13.39	52.36	64.01
23	1200	10	225	1643	9.50	0.179	12.36	67.34	89.74
24	1200	12	225	1786	10.50	0.174	11.54	60.63	103.42
25	1200	08	375	1667	10.	0.159	13.23	34.52	42.36
26	1200	10	375	1705	8.30	0.205	11.23	51.23	65.36
27	1200	12	375	1806	8.56	0.211	10.34	57.01	87.60

Abbreviations Used

FAD = Fabric Area Density (gm^{-2})
FBT = Fabric Thickness (mm)
TMD = Tensile Strength Machine Direction (kNm^{-1})

TXMD = Tensile Strength Cross Machine Direction (kNm^{-1})
BEM = Breaking Extension Machine direction (%),
BEX = Breaking Extension Cross Machine Direction (%)
CBR = Puncture Resistance (kN)
WAD = Web Area Density (gm^{-2})
NP = Needle Penetration (mm)
PD = Punch Density (punches cm^{-2})

RESULTS AND DISCUSSION

Development of Mathematical Models

The initial mathematical modelling work was carried out using the industrial data. Empirical relationships between the fabric dimensional properties and functional performance characteristics were developed using multivariate regression analysis and the multiple regression equations obtained are given in Table 3. Excellent correlation coefficient values were obtained for all the relationships developed from the industrial data. This suggested that these models would allow accurate predictions of the functional properties from the basic fabric elements, such as fabric area density (FAD), and fabric thickness (FBT).

Comparison of the measured and predicted values is illustrated in Figures 2-4. The excellent fit of the predicted values with the measured values confirms that the empirical models developed can be used to make accurate prediction of the functional properties from the fabric area density and thickness values.

Table 3. Predictive Models Based on Dimensional Properties and Functional Performance Characteristics of Medium Performance Geotextiles

Predicted Variable	Regression Equation	Correlation Coefficient (R)
CBR (kN)	CBR = 0.003FAD + 0.8FBT - 1.0	0.990
TMD (kNm^{-1})	TMD = 0.01FAD + 5.2FBT – 12.8	0.998
TXMD (kNm^{-1})	TXMD = 0.043FAD + 5.4 FBT – 9.0	0.987

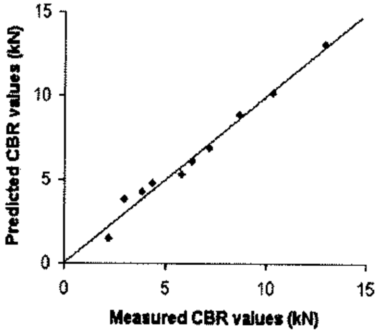


Figure 2. Comparison of Measured and Predicted CBR values

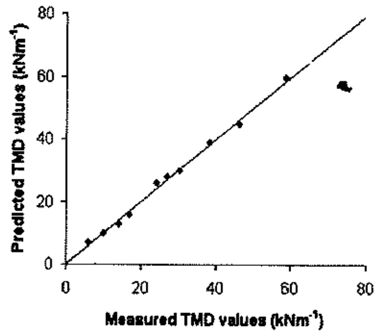


Figure 3. Comparison of Measured and Predicted TMD values

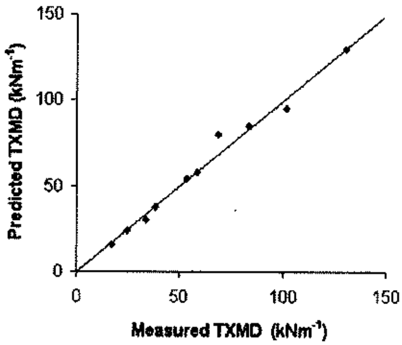


Figure 4. Comparison of Measured and Predicted TXMD

Models Based on the Experimental Geotextiles

In the preceding section it was shown that accurate mathematical models could be developed from the industrial data for the prediction of fabric functional properties from the basic fabric characteristics, i.e. fabric area density and fabric thickness. However, in order to predict the effect of machine parameters on the functional and dimensional properties of the fabric, production of a series of twenty-seven experimental fabrics, under a range of machine parameters, was required. This task was accomplished as outlined in the experimental section of the paper.

In the work reported here and elsewhere [5, 6, 7], multivariate empirical relationships between a wide range of machine parameters, fabric dimensional properties and performance properties of wide range of geotextiles were developed. The results show that the fabric area density (FAD) and fabric thickness (FBT) values can be used together to predict the performance characteristics for a wide range of needlepunched geotextiles with good accuracy.

The effect of the major process parameters (WAD, NP and PD) on the dimensional properties (FAD and FBT) of the needlepunched geotextiles were studied. The empirical relationships between the two sets of parameters were developed by multivariate regression analysis as given in Table 4. The values of the process variables used in this modelling study are given in Table 2 and these were chosen to incorporate the values commonly employed in the industrial production of the needlepunched nonwoven geotextiles for a wide range of applications.

Table 4. Models for Prediction of Dimensional and Functional Performance Properties of Medium Performance Geotextiles From Machine Parameters

Predicted Variable	Regression Equation	Correlation Coefficient (R)
FAD (gm^{-2})	FAD=1.45WAD+14.6NP+0.36PD - 310	0.991
FBT (mm)	FBT=0.006WAD-0.39NP- 0.0078PD +9.5	0.952
CBR (kN)	CBR = 0.011WAD – 0.303NP – 0.0048PD + 3.54	0.984
TMD (kNm^{-1})	TMD = 0.04WAD+2.48NP–0.0015PD – 17.1	0.917
TXMD (kNm^{-1})	TXMD = 0.058WAD + 4.52NP–0.082PD- 10.98	0.936

Web area density (WAD) is considered to be the major contributor to the dimensional properties (FAD and FBT) of the needlepunched fabrics. However, the effect of WAD on the fabric properties is complicated by its interaction with the needling variables. If the WAD is increased under constant needling conditions, then a more open and thicker fabric will result, as more fibres will escape the needling action.

The empirical models describing the relationships between the process parameters and the functional properties of the geotextiles are also given in Table 4. The models given in Table 4 were used to predict the various dimensional and functional properties of a range of Medium Performance geotextiles. The results show that the empirical models can predict the fabric properties with good accuracy, as indicated by high values of correlation coefficients (Table 4).

Multivariate regression analysis technique was also employed to develop mathematical models to predict the machine parameters from a given set of dimensional and functional properties of the needlepunched geotextiles produced. The empirical relationships obtained are presented in Table 5 and these also show extremely high values of correlation coefficients.

Table 5. Models for Prediction of Machine Parameters From Dimensional and Functional Performance Properties of MP Geotextiles Produced

Variable	Regression Equation	R
WAD (gm^{-2})	WAD = 434 + 1.2FAD - 72.7FBT - 10TMD - 7.4TXMD –0.027FAD*FBT+0.008FAD*TMD-0.01FAD*TXMD +0.008FBT*TMD+2.04FBT*TXMD+0.045TMD*TXMD	0.991
NP (mm)	NP =10.7–0.007FAD–1.86FBT+0.25TMD+ 0.26TXMD+ 0.0013FAD*FBT–0.000033FAD*TMD – 0.000025FAD*TXMD – 0.02FBT*TMD + 0.0012FBT*TXMD +0.0022TMD*TXMD	0.915
PD (punches cm^{-2})	PD = 411+1.13FAD–14.6FBT+0.0114TMD – 18.8TXMD – 0.082FAD*FBT–0.014FAD*TMD +0.008FAD*TXMD +1.5FBT*TMD– 0.017FBT*TXMD +0.037TMD*TXMD	0.940

In order to determine the significance of correlation coefficient (R), Student's t test was applied to the values of R calculated for all the properties. Table 6 shows that all observed t values far exceed the expected value of 3.8 for 26 degrees of freedom (d.o.f.) at 0.1% significance level, therefore, we it can be concluded that the correlation coefficients are extremely significant.

Table 6. Significance of Correlation Between Actual and Predicted Values

Property	**FAD (gm^{-2})**	**FBT (mm)**	**TMD (kNm^{-1})**	**TXMD (kNm^{-1})**	**CBR (kN)**
Correlation Coefficient (R)	0.991	0.953	0.984	0.920	0.935
Calculated 't' value for 26 d.o.f.	34.64	14.59	27.28	11.43	13.18
Expected 't' value at 0.1% significance level for 26 d.o.f.	3.8	3.8	3.8	3.8	3.8

Breaking Extension

The breaking extension values obtained for the industrial Medium Performance geotextiles exhibited a very narrow range for a very wide range of area density values. For fabrics with fabric area density range of 200 to 2000 gm^{-2}, the breaking extension values varied between 140% - 160% and 90% - 120% in the machine direction and cross machine direction respectively. This indicated that the mean breaking extension values could represent the actual breaking extension values for these geotextiles. This proposition was examined by applying the Student's t test to the breaking extension data. The calculated t values for BEM and BEX were well below the expected value of 2.4, a value that must be reached at 5% significance level for nine degrees of freedom (Table 7).

Table 7. Significance of the Range of Breaking Extension Values for Industrial Medium Performance (MP) Geotextiles

Value	**BEM**	**BEX**
Range (%)	140-160	90-120
Mean (%)	149.5	100
Degrees of Freedom	9	9
Expected t Value for 5% Significance	2.4	2.4
Calculated t Value	0.55	1.8

BEM = Breaking Extension in Machine Direction
BEX = Breaking Extension in Cross Machine Direction

This signifies that the differences between the individual and the mean values are not significant and could have arisen due to experimental error, therefore, the mean percentage breaking extension values of these geotextiles can represent the breaking extension ranges obtained in both machine and cross machine directions.

CONCLUSIONS

The main objective of the work reported here was to develop mathematical models to allow the prediction of dimensional and functional properties of the needlepunched geotextiles produced under known set of machine parameters. The mathematical models developed show that the fundamental fabric properties – area density and fabric thickness – are quite accurate for predicting the fabric performance characteristics, such as puncture resistance and tensile properties of needlepunched geotextile fabrics. The empirical models developed for the prediction of the influence of the process parameters on the dimensional properties of these geotextiles are also quite accurate. These models have been computed using the Delphi software for the development of the expert system for designing and manufacture of needlepunched geotextiles with desired properties. The design and development of the expert system will be reported in the near future.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support and cooperation provided by the Department of Trade and Industry, UK; Geofabrics Limited, Liversedge, UK; and Bolton Institute, UK.

REFERENCES

1. Hearle, J.W.S. and Sultan, M.A.I, Journal of Textile Institute, Vol 58, No. 2, p103-116 (1967).
2. Purdy, A.T., 'Needle-Punching', The Textile Institute Monograph Series 3, ISBN 0900739320 (1980).
3. Lünenschloss, J. Melliand Textilberichte (English edition), Vol 1, No.2, p128-134 (1972).
4. Rakshit, A.K., Desai, A.N. and Balasubramanian. Indian Journal of Fibre and Textile Research, Vol. 15, June, p41-48 (1990)
5. Shah, T.H., Anand, S.C and Caddick, V.R., Proceedings of the Textile Technology Forum, IFAI Expo, Nashville, USA, October (2001).

6. Shah, T.H., Anand, S.C and Rawal, A., Index 02 Conference, Geneva, Switzerland, April (2002)
7. Shah, T.H., Anand, S.C and Caddick, V.R., Mathematical Modelling for the Prediction of Properties and Performance Characteristics of Needlepunched Geotextiles: Paper accepted for the Seventh International Conference on Geosynthetics to be held in Nice, France, September (2002)

THE APPLICATION OF GEOSYNTHETIC MATERIALS IN GROUND ENGINEERING

C.A. Lawrence, R. Tebay and M. El- Jack
Department of Textile Industries, University of Leeds, UK

Geosynthetics is the generic term for all materials used in geotechnical engineering applications. These materials may be classified into two major divisions namely geotextiles and related products and geomembranes. Geotextiles are specially engineered technical textile fabrics (woven, knitted and nonwovens) and geotextile related products include geomesh, geonets, geocells, geogrids all of which are permable to fluids such as water and gas. In contrast the major function of geomembranes is as a barrier to fluids over a long service life. Geocompites are a sub-group of geosynthetics where two or more of the above products are combined to obtained special functions. This is an interesting and relatively new area of development.

This paper will give examples of applications for these materials, such as earth works, drainage, railway and road construction, and containment systems, looking at spesifications. Relations of geotextiles and geomembranes will be presented and future areas of study will be outlined.

THE OPTIMAL FIBER PREPARATION PROSESS FOR THE NONWOVEN FABRICS INDUSTRY

H. Selker
Trützschler Gmbh&Co.KG, Germany

Most of the nonwoven fabrics are formed from the stapel fibers. For this a wide range of fibres from all kinds of natural fibers to mineral and chemical fibers, are made use of. Optimal fiber preparation lines must be designed for the transportation of stapel fibers in form of bale.

The bale openers, mixers, feeders and cards must be combined in a flexible line as far as possible. For example, to mix a small amount of binding fibers homogeniously, a special floc mixing machine is needed.

At the end of fiber preparation line there is a floc feeder. In this machine set, the following card has an aerodinamic web folder and needle punching or thermal binding system.

Truschler floc feeder is the only active regulator which can regulate the width and length uniformity of SCANFEED FBK web.

The final product manufacturing is guaranteed by the help of SCANFEED.

NEW FUNCTIONAL LAMINATED KNITTED FABRICS TO PROMOTE THE PHYSIOLOGICAL COMFORT OF TECHNOLOGICAL GARMENTS

M. Neves[1] ; J. Neves[1] ; M. J. Geraldes[2]
Departamento de Eng. Têxtil
[1]Universidade do Minho, Portugal
[2]Universidade da Beira Interior,Campus de Azurém, Portugal

ABSTRACT

The main objective of this paper is to describe flexible laminated textile composites, in which two knitted fabrics are bonded closely together by means of an added microporous membrane. This material will be used to promote the physiological comfort of technological garments (sports, leisure and protective wear) through the maximization of the suction properties and perspiration transfer. This fast transfer quality will allow for dry skin throughout the sports activity.
In the production of these laminated fabrics we will use new raw materials, modified polypropylene fibers (star-shaped section with 8 extremities), with very interesting properties in the capillary forces needed for the transport/transfer of the humidity are concerned. In addition, we will use innovated structures of functional knitted goods, where the thermal, physiological and flexible properties have been optimized for the application in this type of garments.
The movement made by perspiration from the skin to the external part of the garment is a consequence of the composite structure of the functional laminated fabric. The knitted sub-layer in contact with the skin, made of polypropylene and cotton and with hydrophobic characteristics will "push out" the humidity through the suction channels, to the more external sub-layer, made exclusively of cotton, and whose hydrophility will promote the movement to the microporous membrane. After the diffusion inside this membrane another knitted sub-layer, made of modified polypropylene, will "push out" the humidity to an even more external sub-layer, made of cotton, that will "expel" the humidity to the external environment.

1. INTRODUCTION

The European Textile Industry has been suffering with the enormous competition from the Asian countries and the so-called conventional products. The European companies decided on other ways, in which the know-how is fundamental for the production of new products, that present greater value.

Comfort is, nowadays, one of the most searched for aspects when one buys and uses a certain type of clothes.

Feeling good with what one is wearing is becoming more and more important in comparison to looking good or acceptable.

It is with the making of new products, with new or improved comfort properties and, consequently, greater utilitarian value that we try to find and maximise thermophysiologic comfort, particularly in sports, leisure and protective clothes.

In any physical activity temperature regulation is one of the most important tasks of the human body. This regulation is part of a complex physiologic mechanism whose objective is maintain the balance between the heat produced and the cooling caused by the evaporation of sweat.

An athlete that, for example, runs for 20 minutes and has an intake of 10 kcal per minute produces approximately 160 kcal of heat. The quantity of evaporation necessary to avoid a rise in body temperature is of 0,276 litres, because for each ml of evaporated water, the body loses approximately 0,58 kcal.

Thus, clothing has a fundamental role in this process of maintaining the balance between the losses and the increases of heat. If one considers that sports activities are often done in not so favourable climacteric conditions (wind, rain, humidity, etc) is seems imperative to study new fabrics that, in situations of intense physical activity will contribute to a greater sense of comfort.

It is important that these new fabrics allow the humidity resulting from perspiration to be rapidly removed, so that the skin is kept dry throughout the whole sports activity.

A fabric which protects from both rain and wind and absorbs body perspiration while keeping it at an ideal temperature.

The project being carried out at the University of Minho aims at contributing for the resolution of this problem by developing functional laminated fabrics using the structures of functional knitted fabrics, that is, structures whose thermal and physiologic properties are optimised.

2. LAMINATED FABRICS DEVELOPMENT

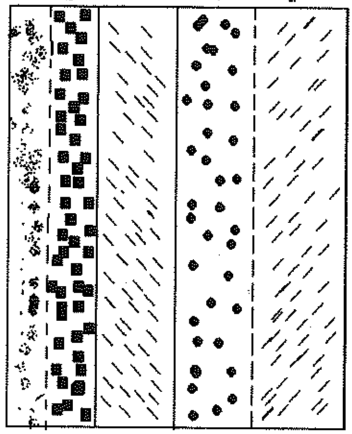
The laminated fabrics so far produced also present 3 layers: the exterior and the interior (lining) ones are polyester/cotton-based fabrics in a 65/35 percentage, and between them there is a microporous polytetrafluoretylene -based membrane. This kind of structures will enable a thermal regulation of the human body by allowing the perspiration to be expelled to the exterior through the membrane and the other layers as water vapour. The dimension of the pores of that membrane is of about 20000 times smaller than a drop of water, which means that even under high pressure, the humidity cannot penetrate the pores. On the other hand, they are 700 times bigger than a water vapour molecule, which allows its fast dispersion to the exterior, thus avoiding the unpleasant accumulation of humidity in contact with the skin. That way, a triple function will always be guaranteed: impermeability, transpirability and wind protection.

The development and production of new fibres/threads, such as micro-fibres, fibres with a special section so as to improve its wetting, humidity transfer, suction and, consequently, thermal properties, have led to the fact that in this project a laminated compound made of 3 layers that is water proof, breathable and wind protecting is aimed at.

Through the development of functional laminated fabrics, one will try to maximise the suction and humidity transfer properties, that is, the physiologic comfort, by using new textile materials, more precisely modified polypropylene (star-shaped section with 8 extremities) with which an increase of the capillary forces of transport/transfer of humidity is verified. One will also use structures of functional knitted fabrics, that is, structures whose thermal and physiologic properties are optimised.

Thus one proposes to substitute the polytetrafluoretylene microporous membrane with another membrane – modified polypropylene-based (transfer and humidity diffusion maximised) – and also to substitute the interior (lining) and exterior layers, made of conventional fabrics, with functional knitted fabrics. That way, the skin will be touched by a layer of polypropylene or polypropylene and cotton (the latter will form the so-called "suction channels"). The layer in contact with the air will always be 100% cotton (or another hydrophilic component) so that a fast evaporation of the humidity to the exterior environment is achieved.

Layer 1: Outer layer (sub-layer *a* is cotton-based and sub-layer *b* is modified polypropylene-based);



Layer 2: Inner layer or lining (sub-layer c is cotton-based and sub-layer d is cotton and polypropylene-based)
Layer 3: microporous membrane is modified polypropylene-based.

3. OBJECTIVES

The main technological objectives of the process are:

1- Develop the absorption layer of a functional knitted fabric structure to be placed in contact with the exterior environment. The solution will involve the study and production of a knitted fabric constituted by two sub-layers interconnected through their own structure. The outer one will be made of cotton – a material exhibiting the hydrophobic characteristics needed, whereas the inner layer will be made of modified polypropylene with appropriate sections (star-shaped section with 8 extremities) and several additives (fire resistance, antifungicides, scents, among others).
2- Develop the separation layer of a functional knitted structure on the reverse side of the article, in touch with the skin, likewise made of 2 sub-layers, cotton and polypropylene-based.
In reality these hydrophobic fibres (of fast drying) are the ones to present the lowest thermal conductivity of all common fibres (6.0 w/m.°K) which means it is the "hottest" fibre of them all. This is a very important aspect, because it

means that the polypropylene fibres allow the diffusion of the humidity of a liquid source to the exterior, or in this particular case, to another fibre.

3- Develop the microporous membrane that will serve simultaneously as a basis for the connection of the layers previously referred to (lamination) and for the transfer of the perspiration from the separation layer to the absorption layer. Polypropylene will be once more the material being used, due to its hydrophobicity, inertia, low density and mainly due to its low vitrification level (-15° C). Microporosity can be achieved through various techniques. One will prefer the so-called chemical processes (spray coating and chemical coating) to the blowing processes that are not as efficient.

4- Objective evaluation and optimisation of the composition and structures of the functional knitted fabrics referred to and of the microporous membrane so as to allow to maintain in a wet state (which simulates the perspiration effects of a high physical effort situation) the thermophysiologic comfort through values adequate to its thermal properties, namely a high thermal resistance and a low thermal absorbtivity.

4. CONCLUSION

Comfort is one of the things people look for when buying and using a certain kind of clothing. This is even more important when concerning clothing to be worn in environmentally aggressive situations, such as in radical sports for example. So, a company with the technologies required for this demand will undoubtedly reinforce its position within a market (sports and leisure) that is showing a significant expansion.

The competitive advantages of the structures to be developed in this project are:

a) Composition of the structure

- Use of functional knitted fabrics (structures formed by interlacement of the stitch, with spaces between them, their size depending on the structure, cover factor and linear mass of the components, differentiated in at least two distinct layers eventually done with different raw materials) capable of conferring water and vapour permeability far better than that of the fabrics used until now.
- Use of a microporous membrane to form the laminate with the functional knitted fabrics, so as to allow an increase of the capillary forces of humidity transport/transfer.

b) Types of used fibres

The use of different materials in the sub-layers in contact with the exterior and the skin (lining), and more precisely cotton and polypropylene with star-shaped section with 8 extremities will bring competitive advantages worth mentioning:

1. Touch/fineness

These articles are 30 to 40% lighter than the ones made only of cotton. When in contact with the skin they really are softer than cotton itself, which translates into a greater feeling of comfort.

The greater extensibility of the polypropylene filaments is another important factor concerning comfort, especially in sports clothes.

As this type of fibres does not cause allergic reactions and enables a dry contact with the skin, the non-existence of a humid micro-climate – prone to the development of micro-organisms (fungus and bacteria) - between the skin and the textile layer is verifiable.

2. Humidity transfer

As the sportsman/woman produces large quantities of perspiration, it is necessary to take that into account. The polypropylene-based separation layer does not absorb it, but allows for its transfer to the exterior cotton sub-layer. This way the skin remains dry and the clothes do not get stuck to the skin. When at rest, the sportsman/woman does not have any feeling of being cold.

3. Water and vapour permeability

With appropriate structures, it is possible to improve the permeability of these knitted fabrics to the air a lot. When in the presence of humidity this permeability is not reduced as the polypropylene fibres do not absorb it and consequently do not swell.

4. Heat transfer

The combination of the structure of the functional knitted fabrics and the characteristics of the polypropylene make it possible to obtain excellent properties of thermal isolation, ever desirable in adverse weather conditions.

5. Dimensional Stability

This is one of the great advantages of the use of these fibres in functional knitted fabrics. Experimentally, it can be verified that the deformation, whether in the direction of the rows or in that of the columns is less than 100% in relation to 100% cotton articles.

The same thing happens in what wrinkles are concerned.

6. "Easy care"

These articles are easy to wash and get dry rapidly. They can be washed by hand or in a washing machine at a temperature between 40 and 60° C.

c) Cost reduction

This product will co exist with the others existing on the market which are sold at a greater price because they have no competition.

The areas in which this project is applicable are the Technical Textiles and Leisure Clothing.

In these areas the objective is to develop functional laminates (technical textiles) that will maximise the suction and humidity transfer properties. In other words, that will provide physical and psychological comfort to the users of Leisure Clothing, even in the most aggressive conditions.

The main results of this project will thus be related with the conception, development and production of composite structures used in sports, leisure and protection clothes, whether used in direct contact with the skin or not, capable of competing and improving on the already existing in what concerns temperature maintenance, wind resistance, fineness, humidity transfer, price, design and colour variety, while bearing in mind other characteristics such as traction, tear, abrasion and ageing resistance.

TEXTILE COATINGS WITH CAPACITY OF THERMAL STORAGE

J.Neves
University of Minho, Dep. of Textile Engineering
Campus de Azurém, 4800 Guimarães-Portugal

ABSTRACT

The diversity and quantity of textile coatings or laminated materials available in the market is increasing along the last decade. This paper analyzes and identifies same applications of these materials and describes how we are able, to make with them, the temperature self-control inside buildings in order to save energy. The weathering damages will be also quantified.

1. INTRODUCTION

In order to get temperature self-control inside buildings, so that the temperature moves between acceptable limits of thermal comfort, we covered these buildings with a "reactive" architectural textile membrane in which are incorporated thermochromic pigments, which behavior, in winter and summer depends on the different conditions of sunstroke (insulation). This solution has the advantage of not presenting any increasing of weight.

The self-control is based on the fact that in winter and cold days, the thermal flux of low frequency waves that pass through the textile membrane is similar to that of black textile membranes given that the low external temperature of the atmosphere doesn't change the colour of the pigment. Within the covering, the heat absorbed by the floor and other internal elements with capacity of thermal storage is gradually released in the form of high frequency waves, which the textile membrane retains inside, indifferent to the colour of the thermochromic pigments, creating a greenhouse effect.

In summer, the colour black of the thermochromic pigment will disappear, allowing the colour white to appear. The result is the reflection of a significant part of solar radiation that strikes on the covering of the building.

In order to apply these pigments over the white coating materials must be chosen an adequate binder for the fixation to the fabrics. The binder and pigment damage must be known.

2. MATERIALS

The textile coating and lamination processes, using polymer layers, have the function of a convenient modification of the external characteristics and physical properties of the textile.
This textile fabric (woven, knitted or non-woven) can be the principal element of the coating, with significant influence on the quality of the final product, or can be useful only as support and consolidation of the polymer layer which functions can be only aesthetics (to mask the imperfections and irregularities of the textile surface), functional (for example, to give better mechanic resistance) or economic (frequently these polymers are cheaper than the textiles with the same weight per unity of area).
As it is evident, the selection of the structure of the woven and the type of the fibre depends on the specifications to the final utilization, like mechanic resistance, dimensional stability or air permeability.
In a general way the resistance is influenced by the structure and the adherence capacity of the polymer is function of the fibre.
The textile coatings evolution is increasing in a gradual way, as a response to the market needs.
Between these applications we can refer technological garments (sports, leisure and protective wear), footwear (as substitute of the leather), home materials (curtains, furniture, divisions, carpets), materials for the exterior (polished floor, tents, sleeping bags, tilt covers, tilt boat, roof coverings for trucks, umbrellas), luggage and packing materials (silos, containers, bags, suitcases).
The future of these materials will be to look for new combinations of polymers and textile materials, as well as to look for new production processes, in such a way that we will be able to reduce the operation costs and quality.

Thermochromic pigments are, as states its name, pigments that change the colour in function of the temperature. They are encapsulated liquid crystals, nematic type. Although it is not clear the explanation for their thermochromic properties it is presumed that the dichroism is a consequence of the thermal equilibrium of the electron movements in the molecules encapsulated.
There are basically three components in the thermochromic system: i) the colour former, which is organic coloured compound, electron donor, that gives the pigment colour in ambient temperature; ii) the acidic colour developer, as phenols, electron acceptors; iii) a non-polar co-solvent medium (often a low-melting point, long-chain alkyl compound) as medium of fat acids that controls the interaction between the first two ingredients (that gives the property of colour changing).

The pigments are usually sensitive to the other components of the coating pastes. In order to protect the crystals and to avoid the loss of their thermochromic properties they are microencapsulated in impermeable polymeric coating.
The pigments are available in various colours and activation temperature. Standard activation temperature of pigments in this case is 32° C.
But the molecular structure of these pigments can be modified when they are exposed to the weather, even if they are microencapsulated. The "weathering" and consequent loss of its "reactive" properties appears when materials are exposed at different climatic conditions as temperature, solar radiation, rainfall, humidity, etc.

3. EXPERIMENTAL

3.1 Equipment

The Spectraflash 600 Plus is a dual-channel spectrophotometer and measures colour in percentage reflectance mode at 10 nm intervals within the visible or extended wavelength spectrum. Analyse was done at wavelength value of 550 nm. The SF 600 Plus light source is a pulsed xenon flash lamp filtered to provide D65 illumination including the UV component for whiteness measurement. These last measurements were made with colourless samples (preliminary temperature treatment).

3.2 Materials and reagents

The samples were obtained by adding microencapsulated thermochromic black pigment to conventional printing pastes, containing four different binders, by screen-printing method. Different UV light stabilizers for UV protection are inserted or not in every binder paste.

3.3 Thermochromic pigment

The black pigments used [1] are spherical microcapsules, with a diameter between 3 and 30 μ, of liquid crystals suspended in an aqueous binder resin.

3.4 Binders and stabilizers

The lifetime of the coated materials and the incorporated thermochromic pigments depends on the use of photostabilizers in the printing paste.

UV absorbers used are effective light absorbers, type benzotriazole: 2-[2-hydroxy-3,5-di (1,1-dimethylbenzyl) phenyl] 2N-benzotriazole and 2-(2'-hydroxy-3',5'-di-tert-amylphenyl) benzotriazole.
The quantity of every incorporated stabilizer is 3 % of the paste.
The processing was applied to the following samples:

Table 1.Constitution of the samples

SAMPLE	BINDER	BINDER/PIGMENT (PARTS)	UV STABILIZER
- 1	N° 1 Acrylic ester copolymer	5 : 3	-
A – 2	N° 1 Acrylic ester copolymer	5 : 3	+
B – 1	N°2 Acrylic and nitrile copolymer (styrene-butadiene)	5 : 3	-
B – 2	N° 2 Acrylic and nitrile copolymer (styrene - butadiene)	5 : 3	+
C – 1	N° 3 Acrylic and vinyl esters copolymer	5 : 3	-
C – 2	N° 3 Acrylic and vinyl esters copolymer	5 : 3	+
D – 1	N° 4 Acrylic emulsion	5 : 3	-
D - 2	N° 4 Acrylic emulsion	5 : 3	+

3.5 Processing

The experiment was done in the weathering machine for 3, 4, 12 and 20 days at conditions:
T = 70° C; R = 1.2 W/m^2 (340 nm) ;
(i.e. max UV rays radiation)

A photo-degradation was observed after processing. The black colour looses the intensity and some properties as whiteness and reflectance were changed (fig.1).

3.6 Results and discussion

Whiteness:
The whiteness was measured after temperature treatment of samples in order to become colorless.

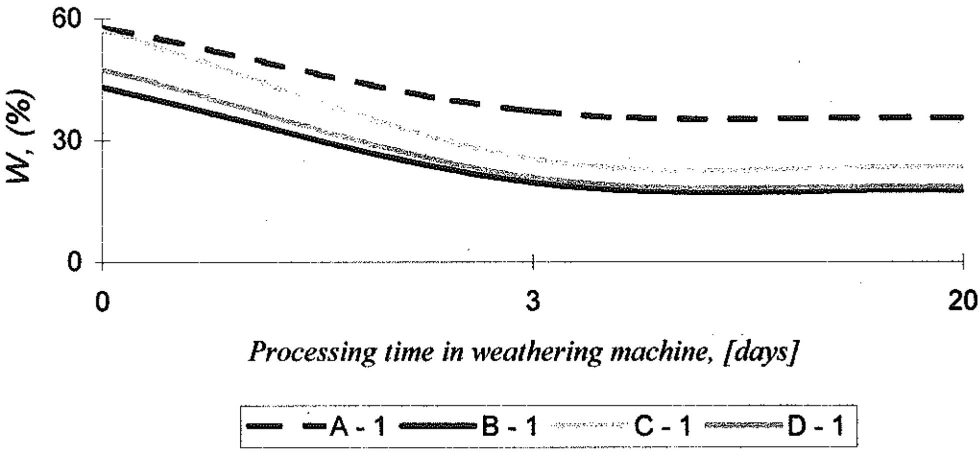


Fig.1. Whiteness of samples without UV stabilizers

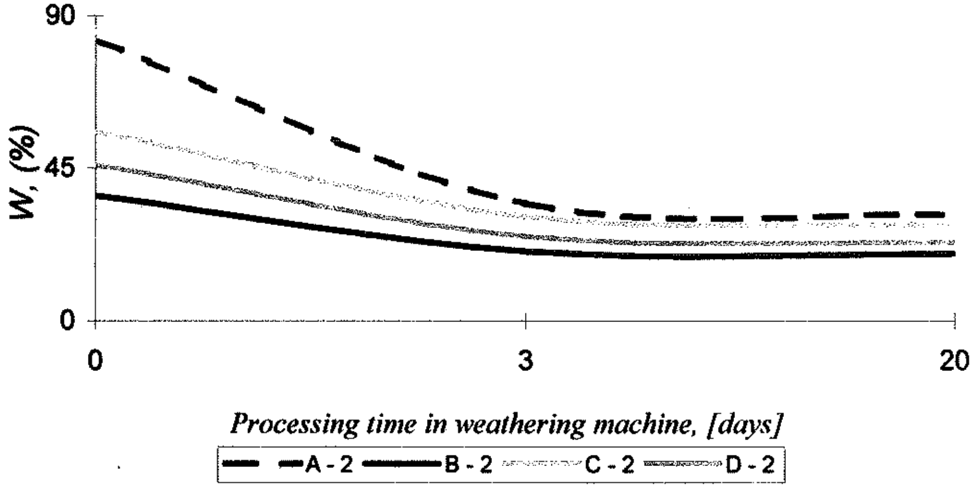
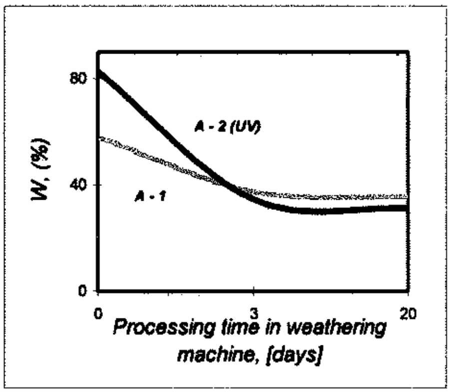
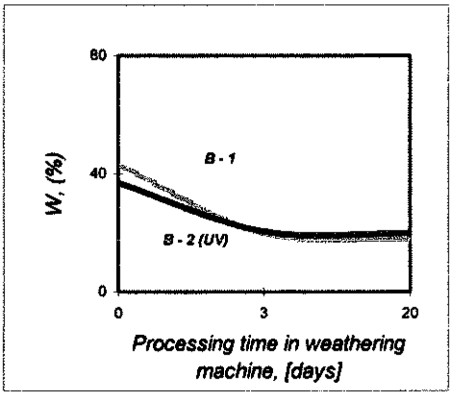


Fig.2. Whiteness of samples with UV stabilizers

The next charts are presented in order to compare the rate of photo-degradation of printed pastes containing and not containing UV stabilizer for the different binders.





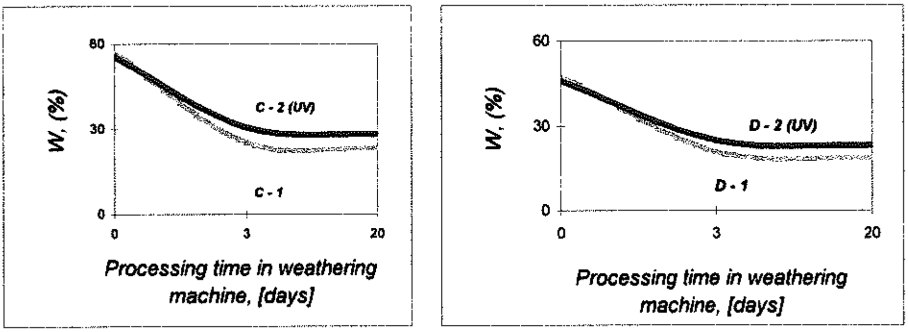


Fig.3. Photo-degradation of printed pastes containing and not containing UV stabilizers in function of the binders.

Table 2. Whitness in function of time degradation

TIME [DAYS] WHITENESS [STENSBY D65/10]	0	3	4	12	20
A - 1	58	37.2	35.4	42.8	31.6
A – 2 (UV)	82.8	31.2	34	34.6	27.8
B – 1	43.1	20.5	19.6	12.2	16.7
B – 2 (UV)	36.9	20.5	21.1	12.7	16.8
C – 1	57.3	25.3	27.3	12.2	23.3
C – 2 (UV)	55.7	30.7	28.2	25.1	25.5
D – 1	47.6	20.8	18.5	18	18.4
D – 2 (UV)	46	24.9	23	20	18.9

4. CONCLUSION

The absorbed UV radiation forms excited states in the molecules of printing paste components, energetic enough to undergo bond cleavage. This energy made to degrade in special the binder molecules and consequently the properties of reflection of the coating when is colourless

Samples A (binder n° 1 - acrylic and nitrile copolymer (styrene - butadiene)) show less rate of photo-degradation. But the colour of the printed samples is not enough intensive and the respective values must be ignored. So, the subjects for discussion are values of samples C (binder n° 3 - acrylic and vinyl esters copolymer) and D (binder n°4 - acrylic emulsion). The results of B are the poorest between all the samples.

The degradation curves of samples with UV stabilizers decrease more slowly than without them as expected. We did not find any differences between the results with the two UV stabilizers used.

The pigment damage is quite interesting because the thermochromic properties had not disappeared. In fact, the effect of degradation appears with the first UV irradiation but the damage stops after the first 3 days in the weathering machine. The black colour looses its intensity and consequently the rate of UV rays absorption is lower, but we saw that all the samples still have thermochromic properties at the end of the experimentation (20 days).

ACKNOWLEDGEMENTS

The author wishes to thank to his laboratory assistant Penka Girginova.

REFERENCES

1-Matsui Shisiko Chemical Co. European Patent-Specification (85100488.9.1989)

TEXTILE COATING – THE KEY TO MODERN, TOP VALUE TEXTILES

R. Schilk
Textilchemie Dr. Petry GmbH,Germany

Summary

Coating, which since a few years ago had been part of the textile finishing, has meanwhile developed to an independent segment within textile processing. No other field of finishing has experienced such a turbulent development during the past years as the field of coating. Nowadays, mainly in the range of technical and fashionable textiles the coating techniques allow for an achievement of effects and properties which would have been impossible a few years ago. As an example we simply refer to the field of micro-porous, water vapour permeable coatings for functional leisurewear. By means of modern coating techniques textiles nowadays can be changed substantially and purposively.

This lecture explains as well the main chemical basis as also the current and modern application techniques. Textile coating offers the textile finisher the possibility to manufacture top value special products for modern and technical applications. With such high-tech textiles increased added valuations can be achieved than within the classical field of textile finishing. Based on selected examples from practise almost unlimited possibilities which the finishers now dispose of are shown in this lecture.

Chemism

The history of textile coating had its beginnings already end of the 19th century when cellulose or natural caoutchouc after having been dissolved in solvents had been spread onto textile backing material. The development of synthetic polymers opened up new possibilities. Whereas formerly solvent-dissolved polymers had been widespread, nowadays for reasons of environmental protection the aqueous dispersions are constantly gaining in importance.

Modified acrylates, vinyl acetates, polyurethanes and latices are the most common chemisms being used today for textile coating.

By variation of the chemical modification and the molar weight different film hardnesses, from elastically soft up to extremely hard, can be achieved. The additional usage of crosslinking agents on isocyanate or melamine basis further improves the properties and particularly the permanence.

Coating Technologies / Application

According to the desired finishing effect different coating technologies can respectively must be used. For this purpose a great variety of application devices are at the finishers' disposal:

- Immersion application (padder)
- Mimimal application (spray, lick-roll, reverse roll coater)
- Blade technique (roller knife, air knife, etc.)
- Rotary screen technique (engraved rollers)
- Transfer coating.

Depending on the individual application technique, the coating material can be applied on the textile either as liquor, paste or foam.

The possible variation of coating technologies and coating material (liquor, paste, foam) opens an almost unlimited field of possible modification of the textiles for their various application purposes, such as:

- functional clothing
- fashionable clothing
- technical textiles
- military textiles.

Outlook/Discussion

Textile coating based on modern, tailor-made chemism and applied by the appropriate technology leads to unique, high grade and top value products, this being a valuable contribution to safeguard the location on the textile finishing industry in Europe.

The discussion after the lecture gives the opportunity for specific questions.

MULTIAXIS THREE DIMENSIONAL WOVEN FABRICS FOR COMPOSITES

K.Bilişik
Erciyes University, Faculty of Engineering, Textile Eng. Dep., Kayseri

1. INTRODUCTION

Textile structural composites have been actively researched since middle of the 70's. Numerous unit cell base structures with their production methods and processes were developed. Material behavior of these structures was identified and limitations of their performance were experimentally described. Design of textile preforms were defined based on end-use requirements and guides to the composite designer. Further study was conducted to find process - structure – property – performançe relationship including analytical formula to predict performance map. In this article, unit cell base developed structure and process with analytical models have been reviewed in this important area of textile engineering.

2. DEVELOPED PROCESSES FOR TEXTILE PREFORMS

Unit cell based developed textile structure and their processing techniques can be considered with fiber interlacement as three dimensional (3D) weaving, 3D braiding, 3D knitting and 3D nonwoven. Three dimensional weaving may be includes interlaced – lattice, noninterlaced – orthogonal, crimped triaxial and multiaxis preforms (1, 2, 3, 4). 3D braided structure is basically developed as four step (full braided), two step (laid-in braided) and angle interlocked (1). 3D warp knitted structure is used with sewing technique to make multiaxis warp knitted preforms. 3D nonwoven preforms were also developed with using sewing or bonding together (5, 6). Similar methodology is applied to develop 3D complex contour preforms with using together classical preperag laminate and sewing techniques. As it seen, development on tẹxtile preforms will be concentrated on new unit cell and processing techniques. Figures 1 to 8 show some of the preforms unit cell. Developments on processing methods have been moved to multiaxis unit cells (2, 3, 4). At the same time processing on preform technology was being automatized with computer aided design and manufacturing. Process developments on multiaxis will be concentrated on complex contoured and large shape preforms.

3. STRUCTURAL PROPERTIES OF TEXTILE PREFORMS AND COMPOSITES

Structural properties of textile preforms are defined by unit cell geometry; fiber angle that is oriented based on reference axis and fiber volume fraction of the composites. Fiber interlacement and interlacement types in the preforms effects to the fiber – matrix interface. Fiber type, number of fiber sets, filament cross – sectional geometry and filament numbers in the tow, surface finishing and hybridization with matrix and matrix forms (commingling, co-weaving) strongly influence to the properties of textile composites.
Strength and modulus of textile structural composites were experimentally investigated. It is concluded that matrix contribution in tensile strength of composites was reduced before plastic deformation and tensile phoneman in the structure was completely depending on individual fiber strength and fiber architecture. Tensile failure causes fiber breakage. Compressive failure of textile woven composite comes from fiber kinking in the unit cell. Resistance to the bending loading in the woven composite comes from the fiber normal to the loading direction and bending failure was seen in the structure due to the tensile and shearing failures. In – plane shear strength in the composite was effected adversely by Z – fiber fraction but it supports to the interlaminar shear strength of the woven structure (7, 8).
Failure mechanism of the textile structural material was investigated. Fracture toughness and crack initiation with crack propagation in the woven composite were entirely effected by type of fiber architecture. It is observed that under the external load first of all matrix becomes tough and it distributes the load to each fibers. When the matrix reaches to the ultimate strength limits, it was sheared. This results plastic deformation in the structure. Fiber began debonding in the fiber – matrix interface region and leads to starting filament breakages in the tow. After all of the filaments in the tow were broken, each tow is disintegrated in the fiber architecture and they are pulled out and loads distributions were changed. Again, they are redistributed entire region. Depending upon fiber breakage, failure is started and cracks propagate based on fractional fiber volume and fiber properties in the fiber architecture (7, 8). It is demonstrated that the effects of impact loads in the 3D woven composite was successfully reduced because of Z – fiber fraction. These fibers carry the impact energy and distributed neighboring regions to prevent damage threshold and reduce damaged area. Therefore, damaged regions in the structure were kept small compared to the classical laminated structure. It is noted that 3D composites showed high damage tolerance properties.

4. DEVELOPED MODELS ON TEXTILE STRUCTURAL COMPOSITE

Propose models on textile composites are mainly based on theory of elasticity and finite elements. Elasticity theory is easily interpreted and not sensible geometrical imperfections. However, it requires failure criteria based on energy method. Final element method is not easily interpreted and very sensible for geometrical definition. It can be used with geometrical model. But it requires strength criteria based on internal stress – strain knowledge in the fiber architecture (8, 11). Developed models "stiffness averaging model" which depends on elasticity theory and is able to predict material elastic constants in which 3D woven composite is assumed as one directional rods. Fabric geometry model is based on volumetric adding of each individual fiber that is assumed solid rods in the specified particular fiber architecture. And model is able to predict material elastic constants (9). In fiber inclination model, material is assumed an inclined lamina oriented at one direction. The model is capable of predicting material elastic constants (7).
Fabric geometry model will be explained explicitly (9, 10). This model was analogy of classical laminate technique. Material was assumed heterogeneous and anisotrop but well ortrotopic. Lamina properties were transferred to the each fiber in the textile composite. Each fiber property was multiply to its volume fraction in the composite. All fibers later on were added to have composite elastic properties. If these are written as mathematical forms (9, 10) :

$$[C_i] = [T_{\varepsilon,i}]\ [C]\ [T_{\varepsilon,i}]^{-1} \qquad \text{(1)}$$

C : Lamina stiffness matrix

$T_{\varepsilon,i}$: Hamiltonian tensor transformation matrix

C_i : Composite material stiffness matrix

$$[C_s] = \sum k_i\ [T_{\varepsilon,i}]\ [C]\ [T_{\varepsilon,i}]^{-1} \qquad \text{(2)}$$

$$[T_{\varepsilon,i}] = \begin{bmatrix} l^2 & m^2 & n^2 & 2mn & 2ln & 2lm \\ l'^2 & m'^2 & n'^2 & 2m'n' & 2l'n' & 2l'm' \\ l''^2 & m''^2 & n''^2 & 2m''n'' & 2l''n'' & 2l''m'' \\ l'l'' & m'm'' & n'n'' & m'n''+m''n' & l'n''+l''n' & l'm''+l''m' \\ ll'' & mm'' & nn'' & mn''+m''n & ln''+l''n & lm''+l''m \\ l'l & m'm & n'n & mn'+m'n & ln'+l'n & lm'+l'm \end{bmatrix} \quad ...(3)$$

$l = \cos\theta$ $\quad m = 0$ $\quad n = -\sin^2\theta$

$l' = \sin\theta\ \cos\beta$ $\quad m' = \sin\beta$ $\quad n' = \cos\theta\ \cos\beta$

$l'' = \sin\theta\ \sin\beta$ $\quad m'' = -\cos\beta$ $\quad n'' = \cos\theta\ \sin\beta$

θ, β : Fiber orientation angle

$$[C] = \begin{bmatrix} c_{11} & c_{12} & c_{13} & 0 & 0 & 0 \\ 0 & c_{22} & c_{23} & 0 & 0 & 0 \\ 0 & 0 & c_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & c_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & c_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & c_{66} \end{bmatrix} \quad ....(4)$$

$c_{11} = (1-v^2_{23})\ E_{11}\ / K^*$

$c_{22} = c_{33} = (1-v_{12}\ v_{21})\ E_{22}\ / K^*$

$c_{12} = c_{13} = (1+v_{23}\ v_{21})\ E_{11}\ / K^*$

$c_{23} = (v_{23} + v_{12}\ v_{21})\ E_{22}\ / K^*$

$c_{44} = G_{23}$

$c_{55} = G_{13}$

$c_{66} = G_{12}$

$K^* = 1-2\ v_{12} v_{21}\ (1+v_{23}) - v^2_{23}$

With micromechanical approach, if each component of stiffness matrix was written by fiber and matrix properties :

$E_{11} = V_f E_f + (1 - V_f) E_m$
$E_{22} = E_{33} = E_m \; E_f / (V_f \; E_f + (1 - V_f) E_m)$
$G_{12} = G_{13} = G_m \; G_f / (G_m \; V_f + G_f \; (1 - V_f))$
$G_{23} = G_m \; / \; (1 - V_f^{1/2} \; (1 - G_m \; / \; G_{23f}))$
$v_{12} = v_{13} = V_f \; v_f + (1 - V_f) v_m$
$v_{21} = v_{12} E_{22} / E_{11}$
$v_{23} = V_f \; v_{23f} + (1 - V_f) \; (2 v_m - v_{21})$

Here,
E_f : Fiber tensile modulus
E_m : Matrix tensile modulus
$G_{f,23f}$: Fiber shearing modulus
G_m : Matrix shearing modulus
$v_{f,23f}$: Fiber poisson's constant
v_m : Matrix poisson's constant

Fiber volume fraction was found based on material unit cell. Proposed fiber volume fraction for braided unit cell is given below :

$V_f = V_y \; / \; V_c = N_y \; L_y \; A_y \; / \; L_c \; A_c$
$A_y = D_y \; / \; 9 \times 10^5 \; \rho$

It is also possible to connect these relationships to the process parameters.

$V_f = N_y \; D_y \; / \; \cos\theta \; A_c \; 9 \times 10^5 \; \rho$ ....(5)
$\theta = \tan^{-1} ((1+k^2)^{1/2} \tan(\theta') \; / \; k)$
$k = u / v$
N_y : Number of fibers
ρ : Fiber density
θ : Fiber orientation angle
D_y : Fiber linear density
θ' : Fiber surface angle
k : Carrier track ratio

Another relation on fiber volume fraction was proposed as follows :

$V_f = V_{fr} / V_c$ ....(6)

$V_{fr} = \pi \; [\, c_i \,(1 + (16 / h\, d^2))^{1/2} + (1 - c_i)\,(1 + (4 / h\, d^2))^{1/2}] \;/\; (6.828 + 1.172\, c_i)$

$h\, d = h / d$

$c_i + c_s = 100$

h : Unit cell length

d : Yarn cross – section

c_i : Fiber fraction in the unit cell

c_s : Fiber fraction on the surface of the unit cell

Fiber volume fraction for multiaxis 3D woven unit cell was proposed as following relations (15) :

$V_{fp} = V_{fw} + V_{ff} + V_{fz} + V_{f+\theta} + V_{f-\theta}$ ....(7)

$V_{fw} = V_w \;/\; V_p$

$V_{ff} = V_f \;/\; V_p$

$V_{fz} = V_z \;/\; V_p$

$V_{f+\theta} = V_{+\theta} \;/\; V_p$

$V_{f-\theta} = V_{-\theta} \;/\; V_p$

$V_p = w \;t\; l$

$V_w = l \;t\; w\; A_w$

$A_w = \pi \; d_w^{\,2} \;/\; 4$

$l_{tw} = N \; M \; l_w$

$l_w = 2 \; T \; d_f + T \; d_z + C$

$C = T \; l_c$

$l_c = \sin\theta \; l_d$

With similar approach, V_f, V_z, $V_{+\theta}$, $V_{-\theta}$ can be defined to calculate fractional fiber volume and unit cell fiber volume.

w, t, l : Width, thickness and length of unit cell.

θ : Surface angle

T : Filling number

N, M : Warp number in row and column

d_w, d_f, d_z : Warp, filling and Z – fiber cross – section.

As it is seen these relations, total stiffness matrix depends on fiber and matrix properties, fiber volume fraction and fiber orientation. These are influenced by unit cell and process parameters. After elastic constants are defined, failure behavior of composite can be described by maximum strain energy criteria.

$$[\sigma] = [C]\ [\varepsilon] \qquad \text{...(8)}$$

If composite's strain energy passes to allowable energy level, failure will be happened.

$U_{c,i} > U_{max.}$

Failure mechanism in composite is explained that contribution of broken fiber in stiffness matrix is deduced. After all fibers were broken, total failure in composite is taken place.

5. RESULTS AND RECOMMENDATIONS

In recent years, textile structural preforms and composites are increasingly importance in the high performance requiring areas. This paper explains recent advances in textile structural composites with regard to fiber – matrix, process and properties relations with developed models.
Further study will be made on development of stiff fiber and tough matrix. Also processing of multiaxis fabrication will be automated to make consistent, high quality and precise preforms. It will be possible to elaborate performance map of textile composite with the help of newly developed testing and analytical techniques.

REFERENCES

1. Mohamed M. H., "Three dimensional textiles", American Scientist, Vol. 78, Nov.-Dec., 1990.
2. Bilişik A. Kadir and Mohamed M. H.,"Multilayered 3D fabric and methods for producing", USPatent No. 5 465 760, 1995.
3. Bilişik A. Kadir., "Multiaxis 3D circular weaving and multiaxis 3D circular woven preforms for composites", NATO ASI series, Kluwer academic publishers, Netherlands, 1998.
4. Bilişik A. Kadir., "Multiaxis three dimensional (3D) circular woven fabric", USPatent No. 6 129 122, Oct. 10, 2000.

5. Dexter B. H.,"An overview of the NASA textile composites program", NASA conference publication – 3211, 1992.
6. Banos J., et al.,"Method and machine for 3D weaving for obtaining woven hollow reinforcement of revolution", USPatent No. 4 183 232, 1980.
7. Chow T. W., "Microstructional design of fiber composites", Cambridge university press, Cambridge, UK, 1992.
8. Cox Brain., et al.,"Tension, compression and Bending failure of 3D woven composites", Acta Metallurgical, 1995.
9. Ko F., "Textile preforms for carbon-carbon composites", NASA reference publication - 1254, Feb., 1992.
10. Gowayed Y. A. And Pastore C. M.,"Analytical techniques for textile structural composites : A comparative study of US – USSR research", NASA conference Publication, Fiber-Tex., 1990.
11. Lloyd D W., "An integrated approach to the mechanical modeling of one, two and three dimensional textile structures", Reports, Dept. Of Textile Industries, Leeds University, U.K.
12. Ko F.,"Three dimensional textile preforms", Textile structural composites, Elsveir Publication, 1989.
13. Pastore C M., "A processing science model for 3D braiding", PhD Theses, Drexel University, 1988.
14. Li W., et al.,"Structural analysis of 3D braided preforms for composites Part 1: The four step preforms", Journal of Textile Institute, Vol. 81, No. 4, 1990.
15. Bilişik A. Kadir., et al.,"Multiaxis three dimensional weaving machine and properties of multiaxial three dimensional woven carbon-epoxy composite", 39th International SAMPE symposium, CA, USA, 1994.

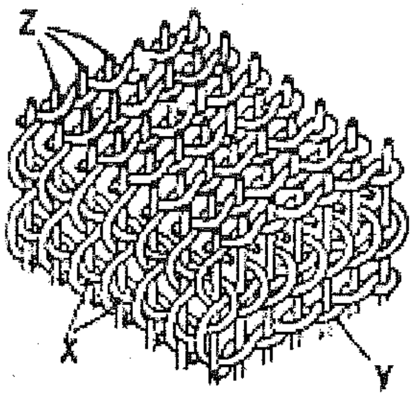


Figure 1. Unit cell of 3D woven lattice structure (12).

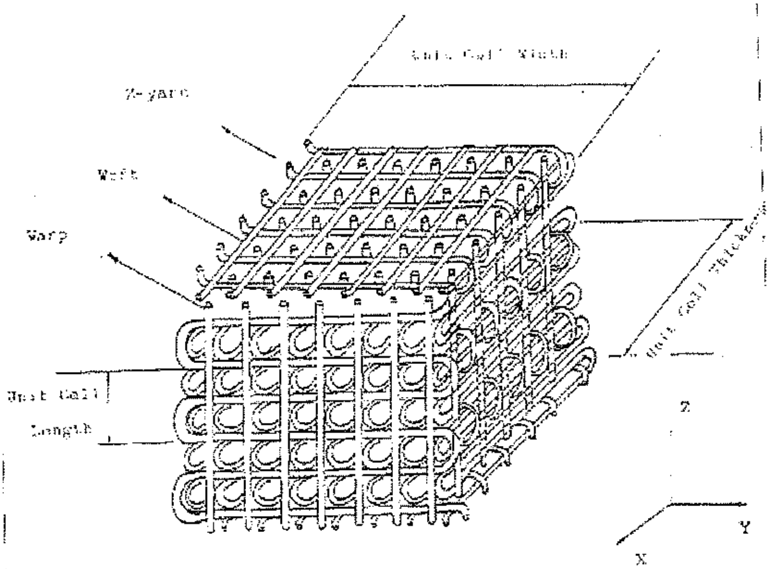


Figure 2. Unit cell of 3D woven orthogonal structure

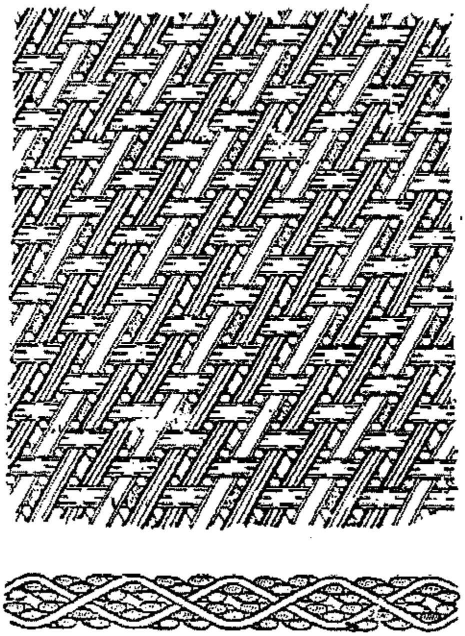


Figure 3. Unit cell of 3D triaxial woven structure (9).

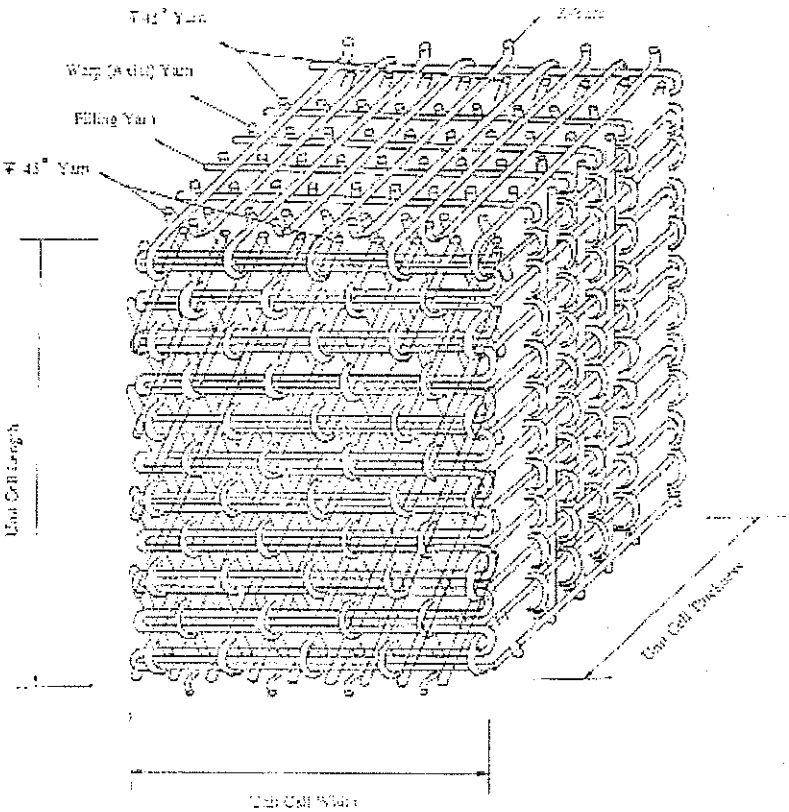


Figure 4. Fiber architecture of multiaxis 3D woven structure (2).

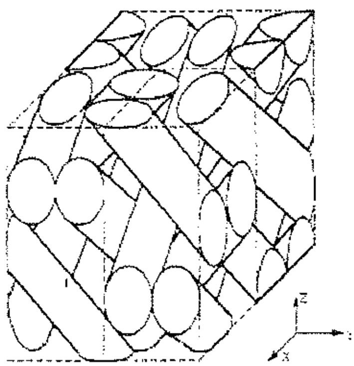


Figure 6. Unit cell of 3D completely braided structure (14).

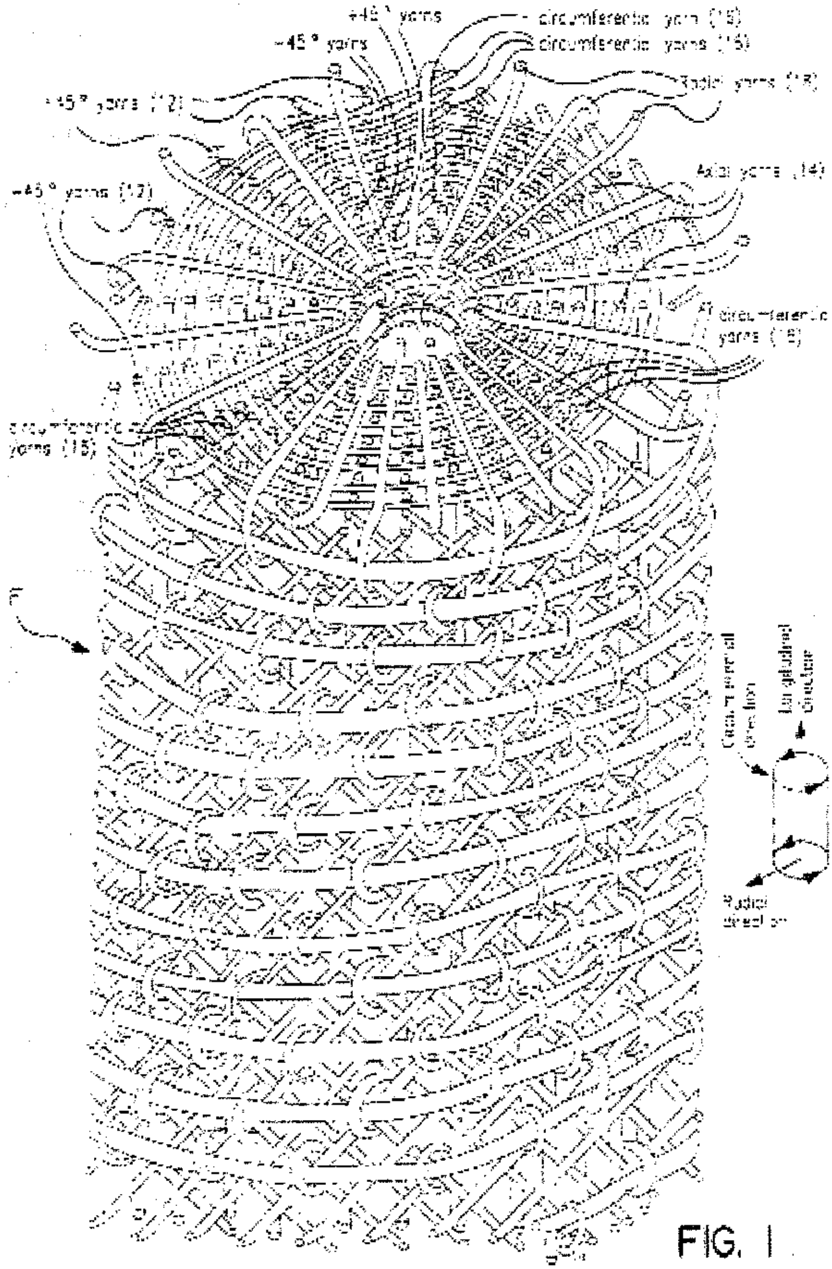


FIG. 1

Figure 5. Fiber architecture of multiaxis 3D circular woven structure (3,4).

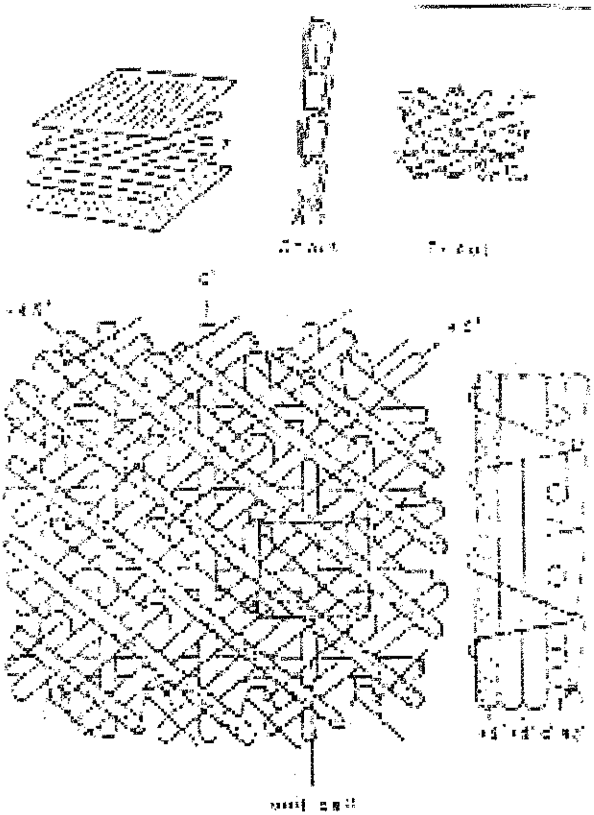


Figure 7. Unit cell of multiaxis 3D warp knitted structure, Karl Mayer (5).

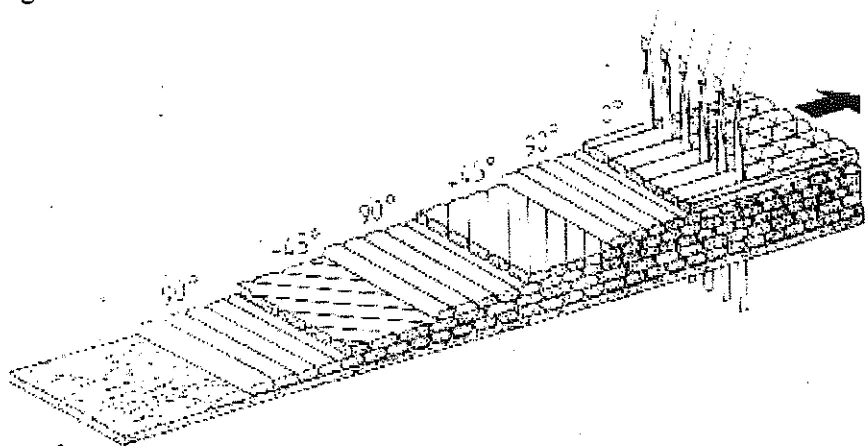


Figure 8. Unit cell of multiaxis 3D warp knitted structures, Liba (5).

SIMPLE PROCEDURES FOR DETERMINATION OF COMFORT CHARACTERISTICS OF PROTECTIVE GARMENTS

L.Hes[1], L. Hesova[2]
[1]Technical University of Liberec, Czech Republic,
[2]SENSORA Instruments & Consulting, Czech Republic,

ABSTRACT

In the paper, three new textile instruments and methods are described and discussed, which are simple and user friendly and which can serve for assessment of parameters related to sensorial and thermophysiological comfort of protective garments. Some instruments can be used also for the production control in textile mills. The first mentioned TRITENS versatile instrument serves not only for the determination of skin contact pressure of elastic garments and for the fast measurement of friction coefficient of flat fabrics, but also for the determination of internal hardness (or degree of compactness) of yarn packages and fabrics. Another very simple patented instrument called AIRBELL enables the determination of air permeability of fabrics. The third item of this presentation is a new measuring method destined for the simple and fast evaluation of fabrics drape by means of the so called DRAPE ANGLE.

Due to their simplicity, any small textile manufacturer could apply these instruments and procedures.

Introduction

Performance garments and clothing characterised by their special functions should offer certain level of comfort to their users also, otherwise their marketing value would decrease. For example, some protective clothing for firemen exhibit perfect protection against high temperatures, but their water vapour permeability is low. Due to limited cooling by sweat evaporation, even some fatal heart attacks of firemen happened in recent years.

Unfortunately, comfort testing systems are costly, and small manufacturers of functional clothing cannot afford them.

The objective of recent research works carried out in the Czech Republic was to develop some simple measuring methods and instruments, which could be purchased even by small textile mills and specialised shops and used for common quality control to convince the customers about the performance characteristics of their products. These instrument need not to be very precise, but they should be easy in handling and in operation, and the results should be understandable to customers. Three of the recent results are simply described in next text.

Methods and instruments
TRITENS versatile instrument

The principle of the instruments measuring unit depends in manual application of mechanical torque momentum by turning of hand and the measurement of the peak value of this momentum applied in the specific measuring tool. The measuring unit was designed in mechanical version [1,2], electronic analogue version and also in electronic digital version [3]. All instrument versions should exhibit the possibility of recording the peak value of the applied torque momentum.

The mechanical version, equipped by the testing needle (1) used for the hardness measurements in yarn packages, is displayed in the Fig. 1. and its use for the hardness measurements will be explained later. The principle of recording the peak torque momentum depends in the use of special torque spring inside the instrument body (3).

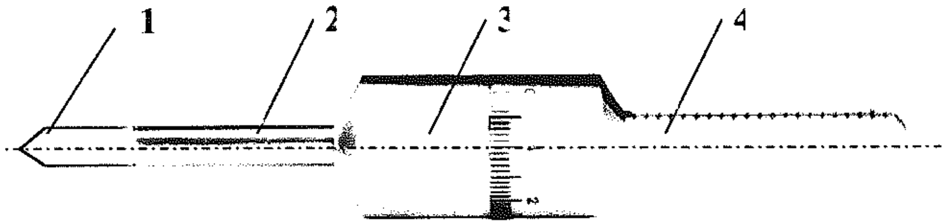


Fig. 1. The measuring unit carrying a needle for the measurement of the package hardness

The more is turned the instrument handle (4), the higher is the torque momentum in the main shaft of the instrument. The maximum angular displacement, and hence the maximum momentum, is then displayed by the extreme position of the slippage dial (pointer).

The electronic versions of the instrument are based on torque the ultra-thin wall tube, whose small angular deformation is measured by means of special strain gages. One end of the tube is manually turned, the other end carries the proper measuring tool. The strain gages signal is conducted to the Wheatstone bridge and the processed either in the analogue amplifier, or by means of a digital micro-controller [4] or PC [5] together with an A/D converter.

As follows from [3], the instruments was first used for analysis of mechanical structure of yarn packages. This structure is quite complicated. The distribution of radial and tangential tensions in packages is very uneven, which may result in serious changes in tenacity and elasticity of yarns and filaments, due to their different position inside the package body. There are some methods, which may reduce the mentioned negative effects, provided that some instrument enabling the determination of mechanical structure of yarn packages is available.

The uneven and varying mechanical structure of yarn packages cause also changes in the shade of packages, subjected to pressure dyeing, due to varying density or compactness of such packages. One bobbin of very low density may absorb more dyestuff and reduce the flow through other bobbins. This phenomenon is frequent in textile mills and may cause more than 10% of badly dyed bobbins, either in the whole volume, or in strips, specially close to the edges. These mainly cotton bobbins have to be re-dyed to black shade or simply scraped. Hence, dyeing experts suggest to avoid this effect by checking the bobbins through their density, since their average hydraulic resistance is proportional to its average density.

The easiest way to distinguish bobbins with different densities is to weight them and measure their volume, but such a procedure is very time consuming. Much easier is to correlate the bobbin hydraulic resistance with their hardness or degree of compactness, which is proportional to its density. In this field, partial solution may offer the classical *Shore Hardness Tester*. Unfortunately, this instrument measures mostly the superficial hardness of the bobbin, which poorly correlates with its internal hardness or compactness, due to irregular arrangements of yarns on the bobbin surface. The obvious solution is, therefore, to measure the bobbin hardness in the depth, which correlates much better with the average bobbin density and, hence, also with the average hydraulic resistance of the bobbin.

The mentioned internal hardness or degree of compactness of bobbins can be easily determined just by means of a new instrument, which measures the integral hardness up to 40 mm depth

If the hardness is measured in a proper reference point of bobbins, those of different hydraulic resistance can easily be sorted out before being subjected to the pressure dying. By means of this new tester it is possible to detect bobbins with different average hardness at the winding machine stage, without having to take them out of the machine. The consequent re-adjustment of the winding machines and avoiding mixing bobbins of different degrees of compactness results in better dyeing quality.

When using the instrument according to Fig. 1, the operator begins by resetting the dial (4) to zero. Then, the selected length of the needle (1), attached to the main shaft of the instrument (2), is inserted into the body of the package in the chosen location, perpendicular to its surface. The operator then steadily turns the handle (3) until a peak of resistance is overcome. The maximum value of the torque causing the needle slip is then automatically displayed on the dial (4).
The principle of indication of maximum torque momentum necessary to create a gap between two elastic layers can be used for determination of pressure between elastic textile products (socks) and the skin. In this case, the measuring flat needle is fixed at the end of an elastic shaft, thus enabling the insertion of a needle between the sock and a skin under small angle, which makes the measurement precise and easy. The searched contact pressure is then proportional to the measured maximum torque momentum.
The tester can be used for the measurement of tension in yarns and filaments also. Here, the couple of yarn forces **F** acting in two pulleys symmetrically arranged in the distance **R** from the main shaft causes the torque momentum **M**, which is measured. The transformation equation respecting the angle α between the yarn segments before and after its passage through the pulley, is given by the relation

$$\mathbf{M} = -\,2\mathbf{R}.\mathbf{F}.\ \sin\alpha \qquad (1)$$

In practical application, the operator should turn the handle to get the pulley into position, where the mentioned angle α reaches 90 +/- 10^{o}(up to 15^{o}) The error of measurement does not exceed 2 % (or 3,5%).
The recent application of the instrument is for determination of friction of flat fabrics. Friction coefficient belongs to important parameters of textile fabrics, since its value affects their behavior during sewing and their contact comfort parameter called handle. Feeling of friction influences also customer's opinion when buying cloth or garments. Unfortunately, common instruments for the friction assessment are too large and costly, and their operation is cumbersome.
The principle of the last application of the already described torque measuring unit [5] depends in measurement of the friction momentum of one fabric against another fabric. As shown in Fig 2, first of the measured fabrics is fixed on the surface of ring shaped body of diameters **D** and **d**, which rubs against the flat surface due to the normal force **P**. The torque momentum **M** of this dry clutch and consequently the friction coefficient μ are given by the following equations :

$$M = 2.\mu..\pi. \int_{d/2}^{D/2} p.r^3 dr \qquad p = \frac{P}{A} = \frac{4P}{\pi.(D^3 - d^3)}$$

$$\mu. = \frac{3M}{P}\frac{D^2 - d^2}{D^3 - d^3} \tag{2}$$

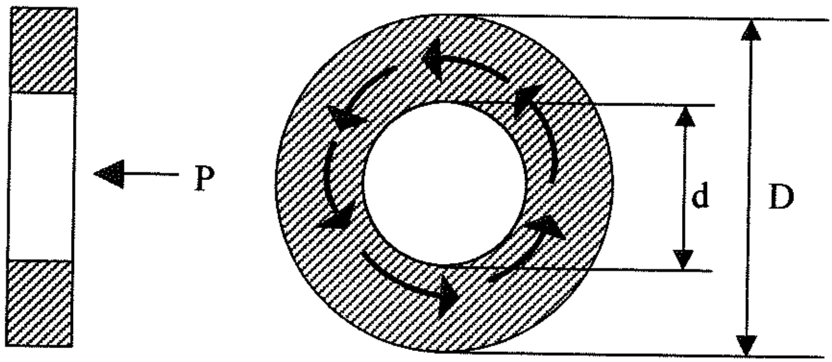


Fig. 2 Geometry of the friction ring used in the tester

The force **P** causing the pressure **p** may result from the mass of the measuring ring (here, the mass inertia affects partially the level of the momentum **M** at the beginning of the measurement).

AIRBELL instrument for determination of air permeability of fabrics

Air permeability of fabrics is very important comfort characteristic of thermal protective clothing. Clothing with high thermal resistance, but too perme-able for wind, cannot protect against cold efficiently. On the other hand, summer garments should be permeable not only for water vapour, but also for the air, in order to enhance the free convection inside the garment system. That is why the air permeability measuring instruments are important item of a good comfort laboratory. Unfortunately, common commercial instruments are quite costly, and many small and medium size textile mills cannot buy then for their laboratories.

A new simple instrument, affordable for most of textile mills, was recently developed in the Czech Republic. This instrument measures directly the time necessary for penetration of 1 litre of low pressure air through the measured fabric. Its principle follows from patent application [6] and next Fig. 2:

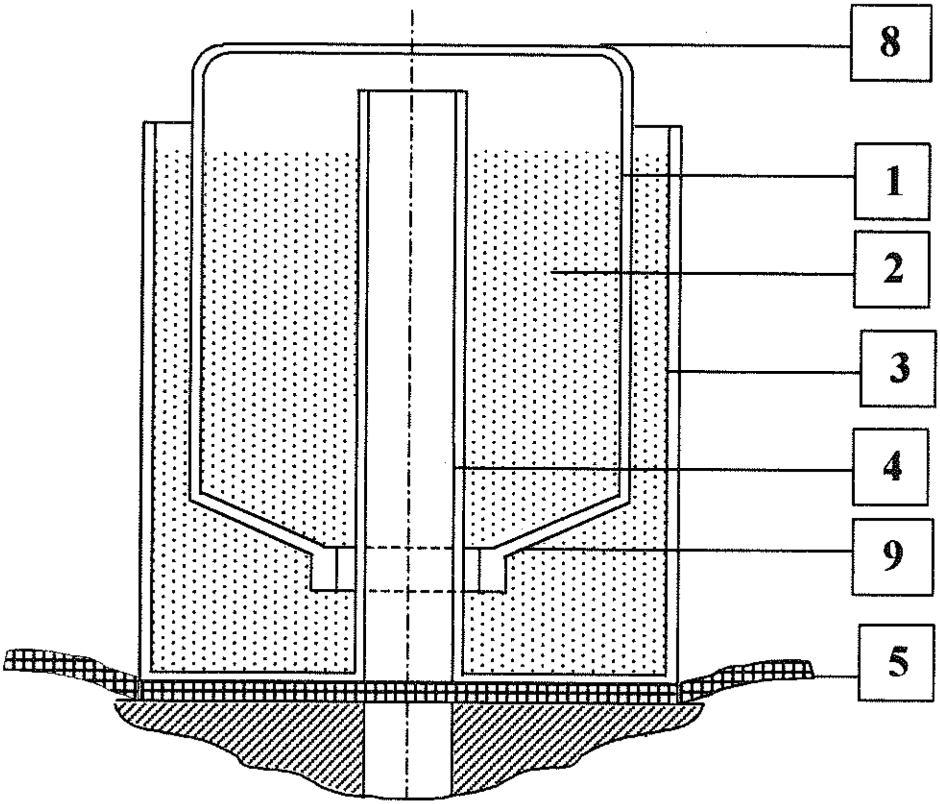


Fig. 3. Working principle of the AIRBELL instrument

Patent claims (simplified)

1.The method of measuring of permeability of porous, especially plain materials for air, the important feature of which is that the measured material is submitted to the current of compressed air which is generated by weight of vertically mobile pressure bell (1) immersed by its open bottom (9) into the working liquid – at best water (2), surrounding the pressure pipe (4) , by which manner from the system of pressure bell (1) – working liquid (2) – pressure pipe (4) a liquid piston is created, which as a result of immersion of the pressure bell (1) into the working liquid (2) drives out air (1) from the volume of the pressure bell, and this air is through the pressure pipe (4) led out from the pressure bell (1) up to the measured sample (5) of material, and time of (gradual) immersion of pressure bell (1) as far as to the end position which characterises the expelled air, and in this way all the parameters for determination of permeability of material in terms of air volume which under known pressure of air passed through the given area of the measured sample (5) material within a unit of time.

Determination of Fabric Drape by Means of Drape Angle

The last fabric parameter to be mentioned is the fabric drape. A new method by L. Hes [7] for determination of drape ability of fabrics, which evaluates the complex effect of two mechanical parameters, is based on bending of a square sample across the 90 degree angle corner of a horizontal plate (table). The bending length is 10 cm and the sample dimensions are 20 x 20 cm. The fabric bent across the corner by its gravity creates a straight drape edge, whose inclination to horizontal plane depends strongly (R = 0,85) on the fabric bending stiffness B [N/m^2] according to Pierce, shear KES-F stiffness G [gf / cm.deg] and on the fabric mass W [kg/m^2]. Provided the sinus of the drape angle is called DA, then the indicated correlation has the form

$$\mathbf{DA = 0,775 - 0,693\,(B/W)^{0,33} - 0,616\,(G/W)^{0,33}} \quad (3)$$

The correlation coefficient to the Cuisick's drape coefficient exceeds, according to our preliminary tests, 0,90. Moreover, the method is extremely fast and simple and no special instrument is necessary.

Discussion

Tritens versatile instrument is already commercialised and used in several European countries, mainly to the yarn package hardness assessment. Other application areas are foreseen.

Yarn package hardness measurement

One possible objection to the use of this method is that the average hardness of a bobbin is only a function of the winding tension of the yarn. This is not the full truth. Factors like the pressure of bobbin holders, quality of bearings and geometry of yarn path, also can significantly change the average bobbin hardness. It was found that the bobbins generally exhibit an internal hardness distribution corresponding to the normal distribution, and that bobbins, whose internal hardness is 20% lower or 20% higher than the average level, may exhibit different shades after their pressure dyeing. To avoid this problem, winding positions, which supply bobbins with these differences in hardness, should be repaired. This procedure was successfully applied in Portugal. The number of badly dyed bobbins was reduced up to half of the initial number

This instrument can serve also for the measurements on warp beams [2], in order to reveal the reasons of irregularities of final fabric, due to irregular yarn ten-sion in warping.

Yarn tension

Unfortunately, dynamical properties of the described versatile instrument used for the yarn tension measurement are not very good, hence the fast yarn tension changes will not be registered. Nevertheless, for the measurements e.g. on creels supplying knitting machines or warping systems this simple and cheap instrument is useful.

Fabric friction

Measurements presented in [4] revealed good reproducibility, when the effect of additional dynamic torque is avoided, due to special software. The newest method does not require any PC treatment and measures with good reproducibility even when the mechanical registration of the peak torque momentum is applied.

Airbell instrument

A simple prototype was built up and preliminary measurements were per-
formed. The instrument showed linear dependence of the measurement time on the number of the tested fabric layers. Nevertheless, the real instrument should exhibit better design, automation means, PC interface etc, hence, some effort is still necessary, to make the instrument reliable and user friendly.

Drape angle determination method

The above mentioned preliminary results were based on measurements on 15 woven fabrics of square mass varying from 100 to 340 g/m^2. Nevertheless, to confirm the applicability of this promising method for evaluation of wearing comfort of protective garments, next thorough research on all kinds of fabrics should be carried on. Recently, ranges of DA values typical for fabrics used for winter and summer suits were determined.

Summary

In the paper, three simple and user friendly new textile instruments and methods were described, which can be used not only for the assessment of selected comfort parameters of protective garments, but also in process control in textile mills. First of them, the versatile TRITENS tester was successfully applied to optimise the internal hardness of yarn packages in approx. 20 textile mills.

Other presented instruments and methods for the measurement of fabric friction, fabric air permeability, fabric pressure and fabric drape have not yet been verified by large scale tests in textile industry, just in research laboratories.

Acknowledgements

Completing and presentation of this work was partially supported by the grant No. LN00B090 offered by the Ministry of Education of the Czech Republic.

REFERENCES

[1] Hes L., Prášil, V., Czechoslovak Patent Nr. 221091, 1981.

[2] Hes L. and Hanzl J., Melliandtextilberichte **69**, 1988, pp. 870-874.

[3] Hes L., Lima M., Ursiny P., Analysis and Optimisation of the Mechanical Structure of Yarn Packages, in: Fiber Society Meeting, Clemson, USA, 1992.

[4] Hes L., Lima M., Martins J., FRICTORQ, Fabric Friction Tester Based on Torque Evaluation, in: Fiber Society Annual Conference, Clemson, USA 1999.

[5] Catalogues of the ALAMBETA, PERMETEST and TRITENS instruments, SENSORA Reg. Liberec, Czech Republic.

[6] Hes L., Hes T.: Czech patent application No. No. 1600-2001.

[7] Hes L., Fridrichova L., Simple Determination of Drape of Woven Fabrics, in: Fiber Society Fall Conference, Lake Tahoe 2001.

TEXTILE MICRO STRUCTURES AND COMPOSITES

S.Gimpel, U. Möhring, W. M.Litz, A. Neudeck, and W Scheibner
Textilforschungsinstitut Thüringen-Vogtland e.V., Greiz, Germany

The integration of microelectronic devices in textiles /1/ can be very useful for communication and controlling aims, especially for occupational clothes and medical applications. Unfortunately microelectronic devices are not really integrated into textile structures: in most cases, they are "stitched" on the fabric or hidden in the textile structure /2/.

Textiles are inherent microstructures with fantastic properties: They are flexible and much more mechanically stable than foils. However till now we do not have the right materials or we apply the wrong materials to use textile structures as electrodes, sensors and even as parts of a microelectronic structure. The aim of this proposal give an overview about promising materials and composite structures as well as techniques to prepare them on textile substrates.

Electrochemical or galvanic deposition processes are the cheapest way to coat or to modify a precursor structure. Metallized threads with a low conductivity are already on the market. They are used to produce textiles to shield electromagnetic waves. The metal layers are thin enough to be undamaged in the textile processing to form the final product, but they are too thin to achieve the conductivity necessary for the applications mentioned above. Further more conducting inks are available to form a pre-cursor structure on textile substrates.

The conductivity of such pre-cursor structures are insufficient for electrodes, sensor structures and to build electronic devices but sufficient for a further galvanic metal deposition, by using special coating procedures and galvanic baths. The precursor structure can be electrochemically modified by metals and even noble metals, as well as by electropolymerisation /3/ and electrodeposition of paint. The metals can be electrochemically oxidized to form oxide structures with semiconducting properties. The textile precursor structure permits to coat various zones by various metals, metal oxides and even new materials. First applications of textile substrates structured in this way will be presented.

REFERENCES

/1/ See for example:
W.D. Hartmann, K. Steilmann, A. Ullsperger, high-tech-fashion, Heimdall Verlag, Witten, 2000 ; B. Lancaze, Funktionelle Textilien, mitttex, 1 (2000) 14 ; Rainer Klose, Denkende Kleider - automatisch wärmen oder kühlen: Ein neues Material revolutioniert die Kleiderwelt, Facts Interactiv. ; B. Müller, "Kraft aus Kunststoff", Bild der Wissenschaft, 10 (2000) ; G. Wallace, "Smart bra heralds age of intelligent fabrics", Technical Textiles International, 07/08 (2000) 32.

/2/ See for example:
Klaus Rönnebeck, Patent, Notrufsystem in Kinder- und Jugendbekleidung, DP 198 43 237 2 ; Symposium of Wearable Computer (1. Meeting 1997 by Georia Tech and IEEE; 2. Meeting 1998 Pittsburg, 3. Meeting 1999 San Francisco, 4. Meeting 2000 Atlanta) ; International Meeting of Wearable Computing 2000 Washington sponsored by Xypernaut (McLean).P. Lukowitz, G. Tröster, "Wearable Computing", Bulletin ASE/VSE, 9 (2000) 15 ; Electro Textiles Company Ltd., www.electrotextiles.co, Peratech, www.peratech.co.uk/profile/

/3/ See for example:
M. Maumy, P. Capdevielle, P.H. Aubert, M. Roche, P. Audebert, A. Neudeck and L. Dunsch, *J. Electroanal. Chem.* 470, (1999) 77 ; A. Neudeck, L. Guyard, P. Audebert, L. Dunsch, P. Guiriec and P. Hapiot, *Acta Chem. Scand.*, **53** (1999) 867.

AIRBAGS FOR AUTOMOTIVE AS SAFETY DEVICES

Y. İkiz, N.Onar
Pamukkale University, Faculty of Engineering, Textile Eng. Dep., Denizli

ABSTRACT

The importance of airbag as safety devices increases in recent years. The wide variety of them is to be found in the form of driver, front-passenger, and side-impact airbags including head and/or thorax airbags. The requirements of airbag depends upon its position in the car. The fabrics used to make a driver's and passenger's airbag are quite different. Current research and developments on airbag are centered on providing more reasonable and more safety fabric and yarn performance properties for using airbag. Generally, airbag fabrics are woven on rapier weaving machines or air-jet looms with a plain weave, rip-stop, or basket weave design. Nylon 6.6 filament yarns widely are used to make the fabric but nylon 6, nylon 4.6, polyester are also used. To meet requirements of airbag; features of used synthetic polymer fibers, weaving processes, finishing processes are to being developed.

Key Words : Airbag fabrics, Air Permeability, Weave Design, LDPF yarns, Polyamide 66.

1. INTRODUCTION

The airbag systems that are protection against head-on collosions are explained as safety devices and automatic safety restraint system. They are built into instrument panel and steering wheel or glove compartment [1, 4]. According to NHTSA (The National Highway Traffic Safety Administration) report in December 2001 , over 118 million (56.1%) of the over 210 million cars and light trucks on U.S. roads have driver airbags. Over 92 million (44.1%) of these also have passenger airbags. Another 1 million new vehicles with airbags are being sold each month. The NHTSA estimates that 7,585 people are alive today because of their airbags. Besides, the NHTSA supposes that the combination of an airbag plus a lap/shoulder belt reduces the risk of serious head injury by 81 percent compared with a 60 percent reduction for belts alone (Table 1)[4].
Data show that more than half of all severe injuries and deaths in automotive accidents are the result of the frontal collosions. Because of this, the production of

frontal airbags is much more than the others. Moreover growth by region is estimated equally and rapidly in 2005. It is expected that the most increasing in the growth has curtain or side-impact airbag while the least increasing that has frontal airbag (Table 2) [1].

Table 1. Frontal Airbag Effectiveness. Percent Reduction in Driver and Passenger Deaths with Airbags (Data from IIHS,2000) [6].

	Crash Type			
	Frontal		All	
	Passenger	Driver	Passenger	Driver
All	18	23	11	14
Belted	14	26	8	12
Unbelted	23	32	14	19

Table 2. World market for airbag systems (systems in thousands) [13]

	System	1997	1999	2001
Western Europe	Driver	11,593	12,730	13,756
	Passenger	8,102	9,406	10,605
	Side impact	3,964	7,144	12,516
USA	Driver	14,550	16,313	16,748
	Passenger	14,196	16,313	16,748
	Side impact	3,276	6,700	9,266
Asia	Driver	6,307	6,807	7,215
	Passenger	4,204	4,805	5,032
	Side impact	1,051	3,203	5,104

There are the wide variety of airbags such as driver side, passenger side, side-impact, thorax, head-thorax, inflatable tubular structure (ITS), curtain, foot, knee bolster, inflatable seatbelts [7]. Airbag assemblies together textile parts as fabric, fibers, coating and cushions have non-textile parts as covers airbag modules, inflators, filters, propellants, housings, initiators, electronics, sensors, covers [12, 13, 7].

Sensors evaluate the severity of the impact in the event of a crash. Under normal circumstances the airbag will deploy if the car is hit at a speed exceeding 20 km per hour. In that time span, crash sensors send impulses to an electronic control module. This module then sends a current inside of the airbag inflator to activate an initiator device which ignites a mixture of sodium azide and metal oxides, added to reduce sodium by product. The inflator expels the hot gas into the bag which primarily consists of nitrogen. The gas passes through a filter and inflates the bag.

The time taken for the decision to deploy and fill the bag is around 35 milliseconds. After absorbing the forces from the occupant, the airbag immediately deflates. The time taken to complete this whole sequence of events is approximately 150 milliseconds [12, 8].

The requirements of the airbag material can be explained as low air permeability (<10 l/dm/min), deflation of air pressure, minimum packing volume and better packageability, pliable, low fabric weight (abt. 170-240 g/m^2), low fabric thickness (abt. 0,26 mm), optimum fabric density (abt. 23/23 l/cm w/w), optimum elongation, elasticity (35/25 %w/w), optimum stiffness, suitable stitch strength, stitch density and design, low friction properties, abrasion resistance, softness, heat stability, heat capacity, coating adhesion, functionality at extreme hot and cold condition, toughness, fog resistance of airbag materials, free of knot, splices, spots and broken ends, tensile strength, withstand very high level of stress (against for extremly rapid), sudden blow-up (<130 N), dimensional stability, resistancy of burst pressure, energy absorption, higher interlacing (to cause improving the tensile strength and air resistancy of the fabric), good buckling resistance, high continuous resistance to tearing (->2500N/5cm w/w), high lifetime (>10 years) without maintenance, non-aging (fungal resp. bacterial resistance) in damp atmosphere, residues preparation content <0,3%, sufficiently indifference to chemicals, ignition mechanism by exploding of a sealing cover, unburnable, recyclable, cost effectiveness, quality [11, 5, 8, 3]. The requirements of airbag depends upon its position in the car. The fabrics used to make a driver's and passenger's airbag are quite different.

Nylon 6.6 filament yarns widely are used to make the fabric but nylon 6, nylon 4.6, polyester are also used. Table 4 and Table 5 show comparatively properties for PA 6, PA 66, PA 46 and polyester [2, 3, 10, 9].

Table 3. Difference for driver's and passenger's airbag [12,10,8,4].

Driver		Passenger	
Coated		Uncoated (because passenger bag are larger so they develop lower gas pressures,)	
Lower denier yarns (yield strong and lighter weight fabrics)		Higher denier yarns	
Smaller volume	35 liters (Europea)	Greater because of retain the gas during inflation	65-100 liters (Europea)
	65 liters (USA)		120-200 liters (USA)
Smaller area for facebag	0,6 m^2 (Europea)	Greater area	3 m^2 (Europea)
	1,5 **Error! Not a valid link.**		4 **Error! Not a valid link.**
Shorter inflation times		Longer inflation times	
Lighter weight fabrics [240 g/m^2(470 dtex), 155 g/m^2(235 dtex)]		relatively heavy [244 or 257 g/m^2 (coated) (840 denier)(linear density)] 175 (uncoated)	
Contained gas is heater		Contained gas is cooler	
Less thicker (0,25 mm)		More thicker, stiffer (0,33-0,4 mm)	
Two circular pieces of fabric sewn together		Tear-drop shaped, made from two vertical sections and a main horizontal panel	

Table 4. The properties of negative or positive properties for PA6, PA66, PA46 and PET comparatively [10]

	PA66	PA 6	PA 46	PET
Melting point TS	0	-	+	0
Strength	0	0	0	0
Elongation	0	+	+	-
Heat resistancy	0	-	+	0
Cost	0	+	-	+

Table 5. Thermal properties of polyamide 66, polyamide 46, and polyester [13]

		PA66	PA 46	PET
Melting point TS	[^{0}C]	255	285	256
Thermal energy to increase T from 20 ^{0}C to TS	[J/g]	620	771	303
Density	[g/cm^3]	1,14 (1,4)(9)	1,18(1,4)(9)	1,36

Polyester has a few advantages over nylon fibers. Polyester fabric has higher cover factor, low porosity and good compaction. Polyester is not as hygroscopic as nylon. As a result, it does not exhibited the dimensional changes due to humidity, temperature cycling and during manufacturing. The other advantages is its ability to be calendered, which significantly improves the packaging and handling. On the other hand, elongation is the first significant advantage of nylon over polyester fibers. It gives more uniform strees distribution along the perimeter seams and enhances fracture resistance at the highest stress points. Greater heat of fusion is the other significant advantage of nylon fibers. Nylon typically absorbs 4% humidity and it provides an additional quenching property [8].

While original yarns/fabrics used were variations of 840 denier nylon66, neoprene coated, today's fabric are primarily nylon 66, lighter denier/dtex, lower denier Per filament (LDPF) yarns, and silicone coated. Typical yarns and constructions being used and evaluated are plain weave [6]:

210 denier/235 dtex, 72x72

315 denier/350 dtex, 60x60

420 denier/470 dtex, 49x49

525 denier/580 dtex, 43x44

630 denier/700 dtex, 41x41

Heat capacity of nylon materials is approximately twice greater than polyester material. Moreover, polyamide 46 has the greatest melting point. Its melting point is 30 ^{0}C higher than polyamide 66 and polyester.

Generally, airbag fabrics are woven on rapier weaving machines or air-jet looms with a plain weave, rip-stop, or basket weave design. However, Milliken claim that at certain densities or yarn counts the stiffness, tear behaviour, and gas permeability of these fabrics is not ideal. In answer to the problem, the company have suggested a twill weave which is a diagonal right and left 2x1 design with diamond or square portions. Milliken are confident that the mechanical properties of this hybrid airbag fabric are much improved. It only remains to improve the excessive extension in one direction and extreme permeability of the fabric under certain situations [12].

The requirements of coating for airbag are good adhesion, antiblocking, long term flexibility, resistance for cycle temperature change (-40 to 250 ^{0}F), ozone resistance, long term stability, low air permeability, low cost.

By means of meet of the requirements, neoprene or silicone coating can be use. Neoprene was the original coating; avaliable, cheap, adequate, familiar, recyclability , longer life- the life of neoprene coated materials, less bulkiness, relatively less stiff. Most new developments involve silicone. The general properties of this are low or no flammability (FMVSS302), abrasion resistance, good flex, low gas permeability (<0,3 cfm), thermal aging stability, low stiffness (for packing) [6].

Recently though, the performance of neoprene has been questioned. Long term evaluations have suggested that it is incompatible with nylon. As a result, fabric elongation and performance at high temperature are lost. Neoprene can also cause nylon fabrics to become brittle, which can drastically reduce the service life of a bag. Additionally, abrasion tests on neoprene coated fabrics have yielded poor abrasion and wear results suggesting that they are not suitable for bags in rough duty vehicles where vibration are more pronounced [12].

A further characteristic of neoprene coating is its high thickness, which renders fabric bulky and difficult to fold. In the future, airbag downsizing will not be achieved by using this coating. Moreover, neoprene is not suitable for recycling since it does not melt on a nylon base. Silicone is environmentally stable and chemically inert which favours a long service life. It is more compatible than neoprene with nylon over long periods when subject to heat ageing. The typical weight of an uncoated fabrics is 150 g/m^2 and coated adds 70-80 g/m^2 [12]. Figure 1 shows airbag processes, respectively.

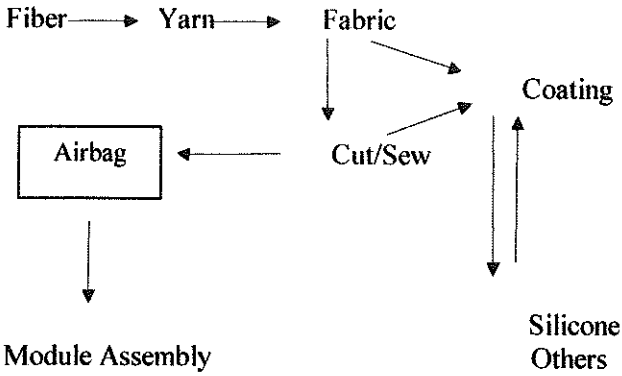


Figure 1. The Airbag Process- a Textile Perspective [6]

To achieve a precise air permeability, airbag material can be calendered. To maintain uniform permeability along the full length and width of a fabric, a calendar with a deflection compensation roller is used. To confer dimensional stability to airbag fabric, it is heat set [12]. Like a parachute, the fabric is folded with extreme care to ensure smooth deployment. A variety of folds are suitable including the accordion fold, reversed accordion fold, pleated accordion fold, and overlapped folds [12].

Airbags are sewn with nylon 66, polyester and Kevlar aramid yarns, the sewing patterns and densities being chosen carefully to maximise performance. Current research and developments on airbag are centered on providing more reasonable and more safety fabric and yarn performance properties for using airbag.

In the near future, aims and trends of production of airbag fabric are reported as to minimize injuries caused by airbags, to reduce for the space needed by airbag, to improve airbag folding behavior, to obtain lighter denier fibers for smaller fabric packages and finer yarns as well as finer filament for example new raw materials such as PA46 (Stanylenka), to use composites, to combine nonwoven and film materials, to use with "cold inflator" technology, to procure the innovations of new coating polymers, new method for alternative of coating and weave design [11, 12, 6, 2, 9, 10].

2. EXPERIMENTAL

2.1 Materials

In this paper, effect of weave design is examined on airbag properties. The four parameters consisted of weave type, ends/inch, picks/inch and yarn denier were chosen to achieve the objective. Seven of different weave designs consisting of plain weave, 2-2 basket, 2-2 warp rib, 3-3 warp rib, warp backed crowfoot, 2/1 warp backed twill, irregular warp backed 5 harness satin are attempted for this objective. The fabrics are woven together pick yarns which are 630 denier nylon yarn with 29 and 34 picks/inch and 840 denier nylon yarn with 26 and 29 picks/inch; and end yarns that are 315 denier nylon yarn with 60 and 90 ends/inch. The total of twenty eight different fabrics sample whose weight from 178 to 253 g/m^2 are produced. The properties of fabric that are fabric weight, fabric thickness, tensile strength and air permeability are determined as suitable for ASTM standards.

2.2 Testing

All fabrics produced were tested to analyze the effects of the described parameters on the fabric characteristics. The following tests and test methods were performed on the fabrics.

Test Types:	**Test Methods:**
1. Fabric Weight	ASTM D 3776
2. Fabric Thickness	ASTM D 1777
5. Tensile Strength	ASTM D 1682
4. Air Permeability	Kawabata KES-F8-AP1 Air Permeability Tester

3. RESULTS AND DISCUSSION

The test results of airbag fabrics are shown in Table 6.

According to the requirement of airbag fabric, fabric weight should be between 170-240 g/m^2 and the fabric thickness should be equal to or less than 0,26 mm. Weights of produced fabrics are supplied between 170-240 g/m^2. The fabric thickness should be equal to or less than 0,26 mm. None of fabrics produced met this requirement. Even the thinnest fabrics which were more than 0.30 mm, are not close to this number.

Air permeability result should be lower than 10 lt./dm^2 min. Air permeability test results were obtained in 10 lt./dm^2 min using Kawabata air permeability tester. Five of 28 fabrics produced met this requirement. Three of them were a plain weave construction and 2 of them were a 2/1 warp backed twill construction. A higher number of warp yarns could not improve the air permeability results on the loose weaves by itself. However, a little higher percent maximum filling texture can easily be obtained with required results for at least the warp backed crowfoot weave.

The requirement of tensile strength of airbag fabrics should be 2500 N/5 cm in both directions. Instron test results were obtained in N/ 5 cm using test method ASTM D 1682. Ten of 28 fabrics had sufficient warp tensile strength. Nine of 12 fabrics with 90 ends/inch and 1 of 16 fabrics with 60 ends/inch met the requirement. These results give strong support to the proposal that increasing the number of ends/inch makes up for the loss in strength caused by fine yarns. Three of 4 satin fabrics with 90 ends/inch could not meet the strength requirement. Because the warp and filling distorted easily, tensile strength and elongation tests could not be performed on loose weave fabrics. Satisfactory results were only for plain and twill weave constructions.

Table 6. Test Results of The Fabrics.

Fabric Number And Fabric Type			Fabric Weight (g/m^2)	Fabric Thickness (mm)	Air Permeability ($lt/dm^2 min$)	Tensile Strength (Breaking force or load) (N/ 5cm)	
						Warp	Filling
1- P	840	26	182.89	0.368	11.175	2286	2866
2- P	840	29	192.45	0.381	7.841	2130	3441
3- P	630	29	171.12	0.330	8.961	2547	2387
4- P	630	34	184.68	0.342	6.114	2143	2537
5- B	630	34	184.55	0.330	19.593	1290	-
6- B	630	29	165.50	0.304	34.244	1114	-
7- B	840	29	190.10	0.368	17.565	1054	-
8- B	840	26	177.40	0.342	31.766	1074	-
9- R1	840	26	176.58	0.342	47.248	1223	-
10- R1	840	29	190.21	0.355	31.902	1341	-
11- R1	630	29	183.33	0.355	22.350	1486	-
12- R1	630	34	166.51	0.317	37.894	1660	-
13- R2	630	34	175.53	0.330	51.484	1530	-
14- R2	630	29	186.21	0.304	71.097	1444	-
15- R2	840	29	165.43	0.330	86.804	1402	-
16- R2	840	26	178.92	0.304	143.561	1290	-
17- C	840	26	224.38	0.381	29.275	2817	1263
18- C	840	29	235.84	0.381	13.096	3491	1960
19- C	630	29	213.91	0.330	20.452	3109	1591
20- C	630	34	230.01	0.368	12.001	3163	2767
21- T	630	34	229.43	0.342	9.296	3881	3499
22- T	630	29	213.60	0.330	21.638	3605	2097
23- T	840	29	238.11	0.381	8.782	3146	2937
24- T	840	26	226.75	0.355	12.462	2682	2222
25- S	840	26	217.97	0.330	108.191	2533	830
26- S	840	29	232.18	0.355	48.162	2051	751
27- S	630	29	208.18	0.304	30.975	2207	770
28- S	630	34	225.36	0.342	15.782	2068	1241

The first section represents the weave type:
P= Plain R2 = 3-3 Warp Rib C= Warp Backed Crowfoot
B = 2-2 Basket T= 2/1 Warp Backed Twill
R1= 2-2 Warp Rib S= Irregular Warp Backed 5 Harness Satin

4. CONCLUSIONS

The project aimed to improve airbag fabric properties by investigating the use of the different denier yarns textures, and weaves in the construction of fabrics. Seven weaves were investigated to determine in a given repeat on fabric behavioral properties. In the warp direction relatively fine yarns were used. To meet airbag fabric requirements, different levels of percent maximum filling texture and percent warp concentration were applied. The fabrics produced were tested and results were analyzed and discussed. A higher number of ends Per inch by itself did not make up for loss in strength caused by using a fine warp in filling direction. On the other hand higher picks Per inch to achieve the air permeability would improve the tensile strength to the required level for the crowfoot, twill and even satin weaves. Most of the fabrics did not met the air permeability requirement. But, this could be achieved with the desired picks Per inch.

All of the fabric thickness values obtained were higher than the requirements. Indeed, because of the relatively fine yarn in the warp direction, fabric thickness should be lower such as 315 and 420 denier than that of the airbag fabrics presently manufactured. Also lower denier Per filament (LDPF) in both the warp and filling would likely achieve lower permeability as well as improve tensile strength, softness and decrease facial abrasion. It is likely that if the fabrics were hot calendered improved results could also be obtained.

REFERENCES

1. Adanur, S. (1995). Wellington Sears Handbook of Industrial Textiles, Lancaster, Pennsylvania, USA, Technomic Publishing Compan, Inc.. Chapter 15.1 Transportation Textiles, pp 495-523

2. Graefe, H. (1998). PA 6.6-Garne für Airbags, Technische Textilien, 41, pp 180-181

3. Graefe, H.A. & Meister, O. (1998). Polyamide 46 garn für schutzbekleidung, Technische Textilien, 41, pp 11-14

4. http://www.acordis-industr-fibers.com

5. http://www.acordis-industr-fibers.com/services/news/TechTex01PA66.pdf

6. http://www.intexa.com

7. http://www.providata.com,airbag.htm

8. Ikiz, Y. (1996). Improvement of Airbag Fabric, Thesis, Philadelphia College of Textiles and Science

9.Konopik, A. & Meister O. (1998). Stanylenka- power af PA 46, Chemical Fibers International, 48, pp 207-209

10. Lindinger, E. (1998). Erfahrung bei der Einführung von PA 46 als Naehfaden für den Airbag Technische Textilien, 41. pp. 181-183

11. Meier, K. (2000), Properties and production process of flat yarns for automotive textiles, Melliand International, 6, pp 58-61

12. Mukhopadhyay, S. K., & Partridge, J., F. (1999). Automotive Textiles, Oxford, UK, The Textile Institute, Textile Progree,V 29, N ½

13. Siejak, V. (1997), New yarns for light-weight airbag fabrics, Chemical Fibers International, 47, pp 438-440.

PERFOBOND: A NEW INNOVATIVE TECHNOLOGY FOR SPUNBONDING

A. Michalon
Rieter-Perfojet- France

1. INTRODUCTION

In the last few years lots of new Spunbonding lines have been installed all over the world, with a yearly growth definitely higher than expected.

The increased numbers of producers as well as the increased volume have reduced the product-selling price compared to the past.

In addition to that, the cost of raw materials suffer continuous fluctuations linked to the oil price, and all that has tremendously reduced the profit margins, making the competition very tight.

For all Spunbonded Nonwovens producers, the only way to survive to this war is to reduce the manufacturing cost. To achieve this, besides the ordinary company economies (minimization of fixed costs), the most effective action is to increase the production, which reduces the incremental cost of goods sold costs. The most effective way to achieve this is to install new high performance/high production lines which have higher linear speed capabilities.

This is the reason why most of the recent installations consist of very big and very productive lines, with multiple beams like SSMMS.

2. PERFOBOND BASIC FEATURES

In order to match such a new market requirement, Rieter Perfojet has recently developed a new technology, called PERFOBOND, which enables production rates much higher than all other technologies presently available, and employs technical features which make the process more effective.

2.1 High Performance

In Figure 1 a graph shows the productivity curve of PERFOBOND, obtained from the pilot line during long term trials using commercially available polymers.

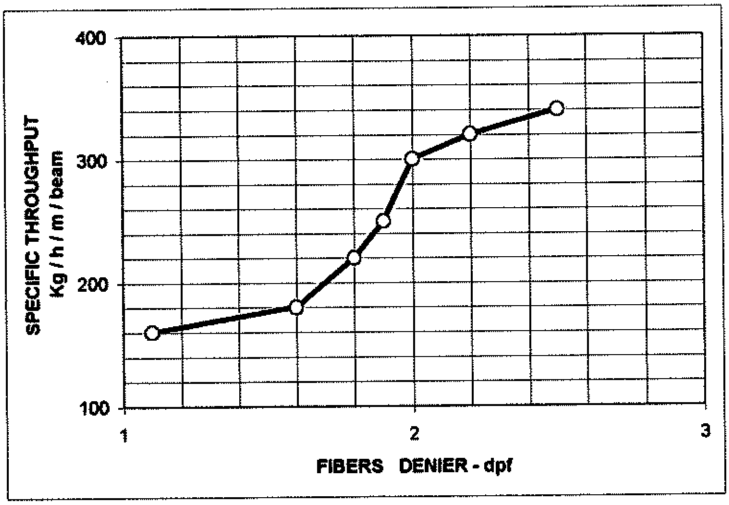


Fig 1. Spunjet SPECIFIC THROUGHPUT versus FIBERS DENIER

From the curve it can be seen that products with standard fibers diameter, ranging between 1,5 and 2,0 dpf, as normally used for most hygiene application, can be produced at a rate ranging between 220 and 300 kg/h per meter per beam, without affecting too much the fibers diameter.

When those values are compared with the ones normally available from other technologies, ranging between 150 and 180 Kg/h, it becomes very clear how large the improvement of throughput is, and the resulting reduction on the cost of goods sold when using the PERFOBOND spunbond system.

The production rates shown are not the maximum capacities of the PERFOBOND system, because the values shown on the curve are based on lightweight products for hygiene applications, up to 30 gsm; whereas heavier product weights with higher denier can be produced at even higher rates.

The way to achieve this goal has been the advanced design of the main equipment steps involved in the process: mainly the Spinning Beam, Quenching, Drawing and Formation Systems.

The **Quenching System,** one of the most critical systems of the process, performs the unique bi-functional role of a separate control for both air temperature and air velocity in three vertical zones, within 0,2 °C and 0,02 m/s accuracy and stability, as Figure 2 schematically shows. This allows for an optimal quenching air profile, regardless of the spinning condition.

The **Spinning Beam** features an especially designed polymer distribution system, made with several distribution plates, which distributes the melted resin in the spinneret in areas as small as 1 cm^2. This distribution system along with a heating system as precise and even as +/- 0,5 °C allows for a flow rate uniformly throughout the width of the spinneret; practically, an identical throughput in each hole of the spinneret.

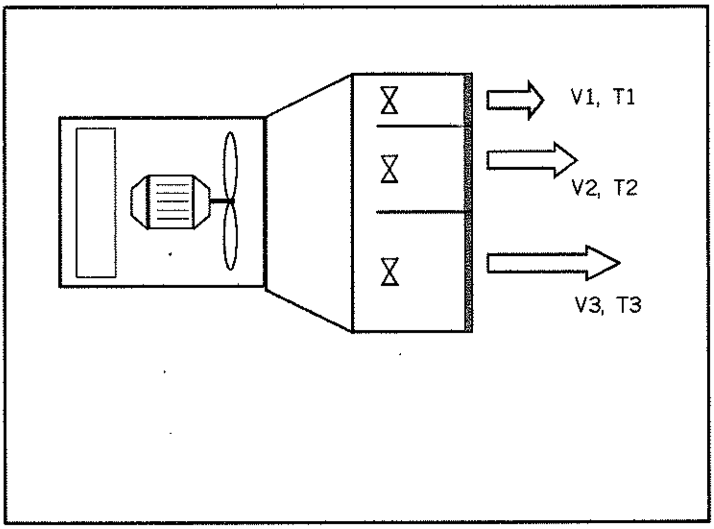


Fig 2 . Quenching System with adjustable Air Velocity and Temperature Profiles

The fiber **Draw System** is a linear air injector (Slot), which has been especially developed; it performs a draw force which is crosswise with a uniformity as even as +/- 2-3%, and uses an automatic setting system for controlling its position and setting.

The **Formation System** which is under Patent Application, has been developed with integrated aerodynamic and electrostatic principles. This allows for control of the jet of air leaving the Slot outlet whilst at same time to splitting the filaments before the deposit of the filaments onto the forming apron.

2.2 Full Process Control

Once a desired performance has been achieved (i.e. the production specifications have been achieved), the most important issue becomes how to reproduce these specifications, and how to keep them constant, that is to say, how to control the complete process.

The more productive the line, the more critical this issue becomes, because any loss of product quality or quantity directly creates a negative affect on the cost of goods manufacturing cost. This issue of cost effectiveness is therefore directly linked to the ability to reproduce any product under sustained production conditions at any given period of time.

All technologies claim, more or less, to utilize sophisticated Control Systems, but in reality, they mostly control equipment parameters rather than process ones.

A typical example is the control of the airflow blown or sucked by any system in the line: where they normally control the fan revolutions or its motor frequency.

In this case, the progressive plugging of a filter for example, which normally occurs during ordinary operations, would require more power from the fan to offset the increased resistance, but since the motor is set to run at a fixed RPM (velocity), the result is a reduction of airflow due to lack of power.
What complicates matters, is that the operator still reads the constant value of the controlled parameter, the fan revolutions, and has the false impression that nothing has changed, when actually, everything has changed.

The loss of product quality might be dramatic in some cases, like in the case of the Quenching System: it processes very slow air velocity, like 1,5 m/s or less, and is therefore very sensitive to the smallest airflow differential.

In the PERFOBOND control system, to avoid such blind changes and false assumptions, only true process parameters are controlled: for the Quenching as example, the controlled parameter is the Velocity of the air which crosses the filaments, not the rotation speed of the fan feeding the quenching zone (Figure 3).

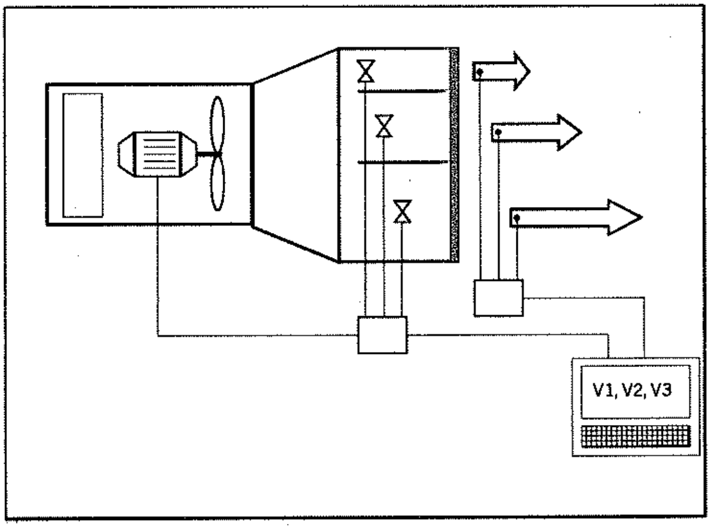


Fig 3. True Control of Process Air Velocity

In addition to that, PERFOBOND technology offers the unique feature of Crosswise Control, where each process parameter is set, monitored and actively controlled every 500mm across the machine width, rather than globally, like the sketch of Figure 4 shows.

This feature further improves the PERFOBOND process reliability and effectiveness, because it detects and avoids small process changes, which may occur in certain areas only, thus reducing off quality production which increases the line yields.

2.3 Stable Process

All conventional Spunbond technologies suffer process instabilities; which constantly affect the fabric properties, and affect the efficiency of the process
The main reason for this instability comes from neglecting the huge volume of air which is moved by the Vacuum System. This air is normally discharged outside the building, putting the building under negative pressure.

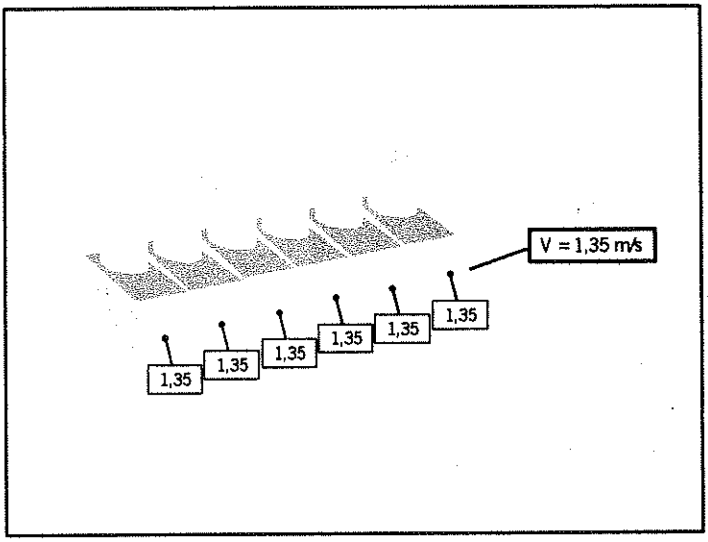
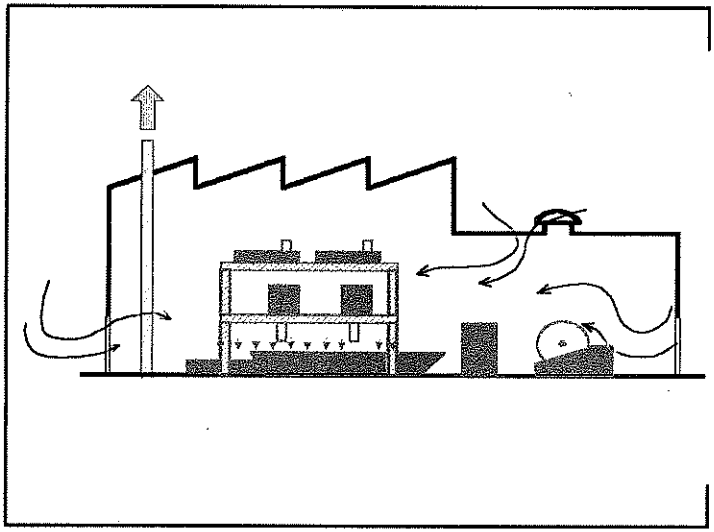


Fig 4. Modular Design for Crosswise Control

As the building, and more importantly, the production environment, is operating under negative pressure, external air enters from all openings, like windows, doors, etc., in its effort to balance the environment (Figure 5). These changes in incoming airflow paths change very often, depending, for example, on which door is open or closed.

In addition to the problems associated with uncontrolled airflow, is the infusion of dust, insects and other foreign matter, which normally enters the production site together with air, and contaminate the nonwoven fabric. Because such uncontrolled suction of external air, the air temperature around the manufacturing line is



constantly changing too, as the incoming airflow is uncontrolled in its temperature. **Thus the Spunbond process, which is very sensitive to both air movement and**

Fig 5. No Vacuum Air Control

temperature practically, runs in an environment where both factors are continuously changing.

Producers normally install all sorts of empirical devices to minimize such problems, for example, cardboard panels to control air paths, screens to prevent insects entrance, and controlled access doors (i.e. Keep This Door Closed), as well as some sort of home designed air handling system to reduce the phenomena.

The designers of the PERFOBOND process are very well aware of these difficulties, and thus have designed systems to resolve these traditional line inefficiencies, which are integrated into the line. These pre-engineered systems prevent the need to retrofit or modify the Spunbond line once the plant is installed.

A so-called Process Stabilization System (PSS), in fact, handles the air of the Vacuum System in order to equalize the pressure inside the building, with the potential to over-pressurize the building if required. It also stabilizes the temperature by means of a controlled make up flow, which either replaces, recycles, or mixes the process and make up air. The airflow paths are also fixed and stabilized by means of pre-defined outlets for blowing the make up air.

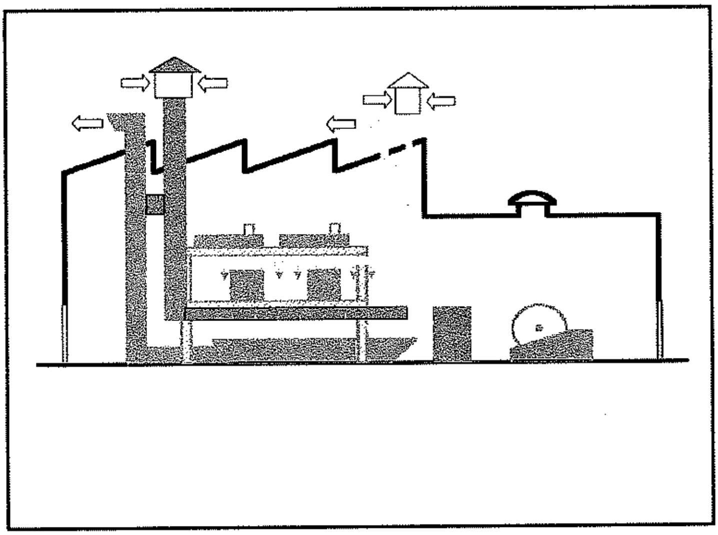
In addition, the building over-heating normally created by heat dissipation of hot equipment, is also eliminated by the Heat & Ventilation System (HVS), which removes the heat, and either replaces it by fresh air, or recycles it for heating colder areas within the plant. This control of airflow and air temperature stabilizes the production environment. Figure 6 schematically shows the integration of those two systems in the PERFOBOND line

2.4 Flexibility

Another advantage offered by PERFOBOND technology is flexibility.

The design engineering philosophy was conceived with all process stages physically separated from each other and independently controlled, like shown in the sketch of Figure 7.

This modularity of process design along with a powerful and flexible control system, allows the operators to run the line in different conditions according to requirements and performance desired at given time.



This flexibility of design has enabled Perfojet to process several raw resin types and brands without any problem. The changes in polymer requires an adaptation of some parameter(s), like the spinning temperature, the quenching air temperature/velocity

Fig 6. Integrated PSS & HVS for Building Pressure and Temperature Control

profile, smoke removal or the drawing, to get the optimal running setup, which is all possible, thanks to the modular design of the PERFOBOND machine.

It is also that fiber diameter do not changes too much in the range of production 220-300 Kg/h, as usually happens in all others technologies, where to any throughput increase follows unavoidable fibers diameter increase.

In PERFOBOND, the Draw Unit, which stretches the fibers, has high draw capacity, and can be regulated independently from the throughput and from other systems.

The easy access to the spinning room then, facilitates the comprehension of phenomena, and the understanding of conditions to be set.

Independent regulation of all systems, mostly quenching, drawing and formation, also allows changing some fabric properties, like:

- Elongation
- Filament Diameter
- Aspect
- Tensile Properties
- MD/CD

Practically, producers have the possibility of getting different products from the same line, by just "turning some knob".

2.5 Plug And Spin

After having signed a purchase contract for a Spunbond line, producers normally

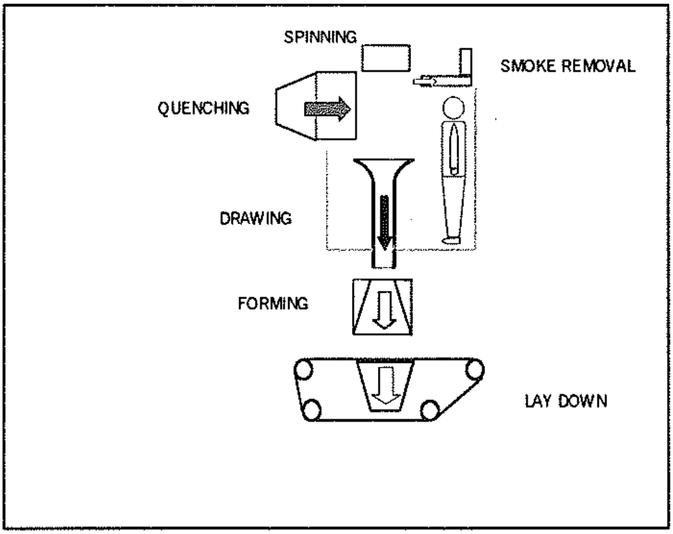


Fig 7. All Independent and Accessible Process Stages

have surprises about what is missing to make the line operating efficiently, or quite possibly, they are already experienced in this matter, and have put into the budget the additional finances to cover the additional costs.

A typical example is the already mentioned air management system, to stabilize the process (similar to PERFOBOND PSS and HVS), which at commissioning is often overlooked or ignored, but shortly after little running, everybody recognizes that air management to be extremely necessary.

At this late point in time, in addition to the additional cost to retrofit corrective measures, the main problems are technical: as the modifications were not designed into the original manufacturing line (as it is in PERFOBOND), and thus it has to be engineered separately. At this time, space constraints normally reduce the effectiveness of retrofitted systems dramatically, and sometimes make it not even feasible at all.
Air filters for the above-mentioned systems have to be provided as well, normally by the customer. The problem here is not concerning the filters themselves (filters are in fact not expensive), but rather, as the volume of air to be filtered is huge, there will be large surface areas with corresponding dimensions, so the problem becomes their location and the access for filter changing. This is a difficult job to retrofit, and involves additional capital investment to cover all of the ductwork, supporting frames, stairs, walkways, etc.

PERFOBOND features an integrated filtration system, which is supported and accessible from the line frame, and thus does not need any extra engineering, or work, or investment.

There are similar types of problems seen with all of the piping, cabling and ductworks, since they normally have to be engineered by the customers separately. Therefore again, the problem is not the material cost, but the engineering and technical feasibility to snake the pipes, cables and ductworks within an existing frame.

For this reason, PERFOBOND is designed with integrated ductworks, cabling and piping, in order to minimize their length, optimize the space, and most importantly, eliminating the customer from of any kind of extra engineering responsibility.

3. CONCLUSIONS

A new concept of Spunbond line has been described: PERFOBOND, by Rieter-Perfojet. The advantages of this process are not seen in further developments into the fiber/fabric capabilities, but rather in improving quality, productivity and reliability of standard Spunbond technology.

Therefore, the advantages of the PERFOBOND process are derived through the innovative and exclusive concepts, based on the elimination of technical problems and limitations which conventional processes normally suffer.

As a result, PERFOBOND produce conventional lightweight products at the incredible rate of 300 Kg/h per meter, per beam.
PERFOBOND also performs the unique feature of controlling all air handling systems by means of the true air velocity at its utilization point, and each half a meter across machine width.

POSTER PRESENTATIONS

THERMAL ANALYSIS AND PERFORMANCE PROPERTIES OF THERMAL PROTECTIVE CLOTHING

B.Kutlu, A. Cireli
Dokuz Eylul University Engineering Faculty, Textile Eng. Dep., İzmir

ABSTRACT

In this study, a test apparatus for thermal protective performance test , which is one of the important tests for evaluating the fabric insulation properties, was established in Textile Quality Control Laboratory at Dokuz Eylul University Textile Engineering Department. Four different types of outer layer fabrics, one thermal barrier (inner liner quilted on aramid felt), and one inner liner were combined together to obtain a multi-layer construction. By using the apparatus, containing radiant and convective heat sources, thermal protective performance (TPP) ratings were measured for these fabrics. Utility of the apparatus and repeatability of results were examined. In addition, effects of repeated washing processes on TPP ratings were examined.

1.INTRODUCTION

Modern technological developments have brought with them a vast increase in the kinds of hazard to which workers are exposed. Most of these hazards are encountered in work-places ([1], [2]).

Personal protective equipment, which includes personal protective clothing and gear such as respirators, face masks, and other controls, forms a barrier between the person and the hazardous environmentThe dangers are frequently so specialised that no single type of clothing will be adequate for work outside the normal routine. Protective clothing made from woven, knitted, and nonwoven fabrics have been designed to suit specific requirements, and pèrformance-evaluation techniques to simulate the workwear conditions have been developed ([1], [2], [3]).
Work-place hazards can be grouped in the following general categories:

a. <u>Chemical hazards</u> are from liquids (sprays), gases, or dust occurring in chemical industries during production, distribution, storage, use and disposal.

b. Mechanical hazards (cut, tear, puncture) may involve ballistic threats encountered in military, police and law enforcement work; ballistic threats related to personal assassination, riots, hunting, and mine explosions; or threats from sharp objects encountered in packaging, glass, and lumber industries.
c. Radiation hazards are from x-rays and gamma rays (ionising radiation) and microwaves (electromagnetic radiation waves) and high-transmission power lines (non-ionising radiation).
d. Biological hazards occur by transmission of diseases caused by micro-organisms. Insidious viruses such as hepatitis and human immunodeficiency virus (HIV) may be transmitted by handling body fluids and/or contaminated laundry.
e. Thermal hazards can be due to flames, heat, molten-metal splashes or hot gases and vapours. Fire fighters, foundry and glass manufacturing workers, and utility services, aerospace, and military personnel may encounter hazards associated with thermal environments.

To overcome thermal hazards, heat and flame resistant fibres are used to produce thermal protective clothing. Thermal protective clothing should not ignite, they should remain intact, not shrink, melt, or form brittle chars that may break open and expose the wearer; and they should provide as much insulation against heat as is consistent with not diminishing the wearer's ability to perform a task. In Table.1, there are some occupations in which the hazards from heat and flame are such an integral part of the job that the worker needs to wear protective clothing more or less continuously ([1], [2], [3]).

The growing concern regarding health and safety of workers in various sectors of the industry has generated regulations and standards, environmental and engineering controls, as well as tremendous research and development in the area of personal protective equipment. There are a number of different tests used for evaluating thermal characteristics of protective clothing, such as ease-of-ignition tests, flammability tests, heat-release-measurement tests, extinguishability tests, tests for measuring thermal insulative properties of fabrics and thermo-person full scale garment burns. In this study, thermal protective performance test method, which is one of the important test methods for measuring fabric's insulative properties, is used for thermal analysis ([2], [7]).

Table 1. 1 Hazardous Occupations Requiring Protection Against Flame and Heat

Industry	***Flame***	***Thermal Contact***	***Radiant Heat***
Foundry (Steel and glass manufacturing, metal casting, forging)	*	**	**
Engineering (Welding, cutting, boiler work)	*	**	*
Oil, gas, and chemicals	*	-	-
Aviation and space	*	-	-
Military	**	*	*
Firefighters	**	*	*

** Major hazard; * subsidiary hazard; - minor/no hazard,

1.1 Thermal Protective Performance Test Method

Total heat energy from a fire can cause a worker's clothing to ignite or melt; it can cause the clothing to break open and subsequently cause severe burns to skin. Burns are classified in three categories. First-degree burns represent pain, where skin becomes red but does not blister. Second-degree burns involve blistering of the skin, and epidermis must regenerate. Third degree burns cause the epidermis to be destroyed, the skin cannot regenerate itself, and scar tissues form ([4], [7], [8]).

The work of Stoll and Chianta in the 1960's helped to quantify the response of human skin and tissue to a source of heat energy. When human tissue is raised from the normal blood temperature of 36,5°C to 44°C, skin burns begin to occur, at a rate that depends on the raised temperature level. For example, at 50°C, damage to the skin is 100 times faster than at 45°C, and at 72°C total destruction of the epidermis occurs almost instantaneously ([4], [8]).

Thermal protective performance test method uses data from the work of Stoll & Chianta to make estimates of the time it takes for second degree burn damage to begin to occur for a given exposure (Figure 1.1.a). These data are converted to the total amounts of energy that must be absorbed by the skin and to skin temperature rise to cause second-degree burns for a given amount of exposure heat and length of exposure (Figure 1.1.b). Temperature rise recorded can hence be compared with this criterion to estimate the time required to produce a second-degree burn ([4], [7]).

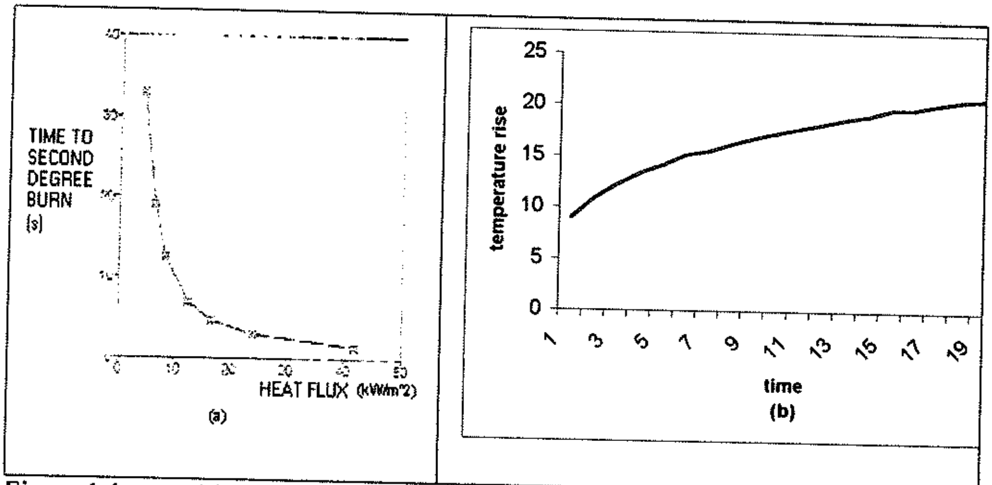


Figure 1.1 (a). Stoll criterion for time to second-degree burn for various incident heat fluxes on bare human skin (b). Stoll Curve, temperature rise versus exposure time for given amount of exposure heat

Thermal protective performance test method involves a heat source, which can be a burner (or burners) to supply convective heat or only a radiant source to supply radiant heat or the combination of the two to provide radiation and convective heat together. Test apparatus set up for this study is based on the NFPA test method 1971-1991 (Figure 1.2). This equipment combines two burners and a bank of nine quartz tubes controlled to provide a 50% radiative and 50% convective heat flux at a total flux of 84±5kW/m^2 (2±0.1cal/cm^2.s). A sliding shutter protects fabric sample before and after the test run. Specimen is 150mm by 150mm and placed vertically on the heat source, between upper and lower mounting plate. Heat sensor is mounted in direct contact (there is a spacer in the case of single layer fabrics) with the back surface of the fabric that would be towards the skin. The heat sensor consists of a copper calorimeter and an insulating board in which calorimeter is mounted. The copper calorimeter is blackened and has 40 mm diameter with the thickness of 1.6 mm and four thermocouples are secured in the disk, positioned at 120° intervals and at the center ([6], [7], [9], [10]).

The thermal protective performance (TPP) rating of a fabric is the amount of energy in cal/cm^2 which must be supplied to the fabric until it is estimated that second degree burns of the skin behind the fabric would occur, using the Stoll criterion. As the heat flux of 2 cal/cm^2.s is used, the TPP rating is simply found by multiplying the time to exceed Stoll second-degree burn criterion by two. The larger this number, the greater the protection factor of the fabric system. ([7], [9], [10]).

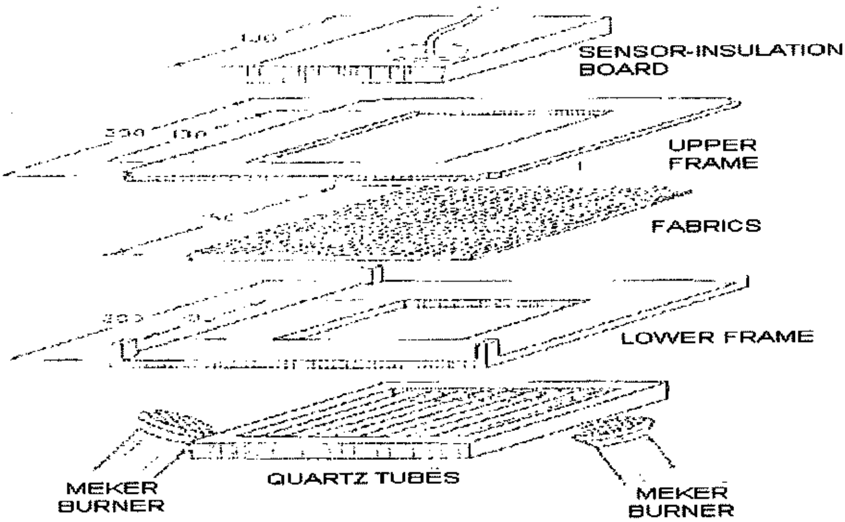


Figure 1.2 Schematic of the NFPA 1971-1991 test apparatus

Although thermal protective performance test is one of the major tests used to evaluate the performance of thermal protective clothing and is demanded in the specifications of military and firefighters protective clothing, the TPP test could not be applied in Turkey. When there was a demand to do this test, fabrics had to be sent abroad; and this caused the loss of money and time. So we established a test apparatus based on the NFPA Test Method 1971-1991 in Textile Quality Control Laboratory at Dokuz Eylul University Textile Engineering Department. In addition, the effects of repeated washing on TPP ratings were examined [6].

2. MATERIAL AND METHOD

2.1 Material

Fabrics used in this study are listed in Table 1.2.

Table 2.1Fabrics used in this study

Code number	Material	Used as	Unit Weight	Width
1	%60 Nomex Delta A / %40 Para-Aramid	Outer shell	230 g/m^2	160 cm
2	%40 PBI / %60 Para-Aramid	Outer shell	200 g/m^2	160 cm
3	Nomex III (+ %1 steel fibre)	Outer shellv	260 g/m^2	160 cm
4	Nomex Delta T / %2 Antistatic fibre (P140)	Outer shell	190 g/m^2	160 cm
5	% 50 Nomex / % 50 FR viscose	Inner liner	130 g/m^2	160 cm
6	Aramid / FR-viscose(35/65) guilted on %100 Aramid felt	Thermal barrier + inner liner	Fabric:110g/m^2 Felt: 190 g/m^2	160 cm

2.2 Test Method

Before testing, fabrics are washed for a total of 10 cycles. Before washing, and after 1cycle, 3, 5, and 10 cycles, the TPP rating of each specimen is measured. The effects of laundering on TPP ratings are examined. Washing was performed in an automatic washing machine at 40°C and at a program (approximately 1 hour length). The amount of detergent used is 5g/l and the liquor ratio is 1:5.

Three specimens of each outer shell fabric and of each assembly of one outer shell with thermal barrier fabric, and also each assembly of one outer shell with inner lining fabric were exposed to a 50/50 of convective/radiant heat flux density of 84±5kW/m^2 (~2±0.1cal/cm^2 s) specimens being washed (1, 3, 5, 10 times) and unwashed. If disparity between the three readings exceeded ±8% of the mean value, testing was continued until three consecutive readings within these limits were obtained. The fabric layers were sewn together so as to just touches one another. Also, the calorimeter was mounted in contact with, but without pressure, against the back of the specimen. The curve recorded in terms of the rises in the temperature was compared with Stoll's second-degree burn criteria in order to calculate the protection time. The TPP ratings were determined by multiplying the protection time by the heat flux density of 2cal/cm^2 s.

3.RESULTS AND DISCUSSION

Table 3.1, 3.2 and 3.3 show data obtained on the single-outer layer fabrics, two layer fabrics and three layer fabrics respectively. Data are reported in tolerance time and in TPP ratings.

Table 3.1 TPP test results of single layer fabrics

Fabric	Tolerance time (TT) (s)	TPP cal/ cm^2	TT (s)	TPP cal/ cm^2	TT (s)	TPP cal/ cm^2	TT (s)	TPP cal/ cm^2	TT (s)	TPP cal/cm^2
	Before Washing		1st Washing		3rd Washing		5th Washing		10th Washing	
1	5,27	10,54	3,5	7	3,96	7,92	4,36	8,72	4,5	9
2	5,73	11,46	6,2	12,4	4,93	9,86	4,83	9,66	5	10
4	3,53	7,06	3,73	7,46	3,2	6,4	4,2	8,4	3,76	7,52
3	5,4	10,8	3,76	7,52	4	8	5,63	11,26	5,33	10,66

Generally, results of measurements of single layer fabrics show close values. But the best performance of all is exhibited by PBI/p-aramid 40/60 fabric with code of No.2; and the second by Nomex III fabric with No.3.code. One of the reasons of lower TPP rating of No.3 may be the construction of the fabric, because it has a compact structure and this may increase heat transfer by conduction.

Table 3.2 TPP test results of two layer fabrics

Fabric	Tolerance time (TT) (s)	TPP cal/ cm^2	TT (s)	TPP cal/ cm^2	TT (s)	TPP cal/ cm^2	TT (s)	TPP cal/ cm^2	TT (s)	TPP cal/cm^2
	Before Washing		1st Washing		3rd Washing		5th Washing		10th Washing	
1+5	7,1	14,2	8,96	17,92	9,83	19,66	9,7	19,4	9,9	19,8
2+5	7,6	15,2	11,96	23,92	10,36	20,72	10,8	21,6	9,86	19,72
4+5	7	14	8	16	8,5	17	9,8	19,6	10,6	21,2
3+5	7,3	14,6	8	16	8,4	16,8	11,16	22,32	9,18	18,36

From this table, it is obvious that making a layer with an outer layer fabric and an inner layer fabric even with a low unit weight and low thickness is very useful for thermal performance. As the maximum TPP rating in single layer samples is 12.4, the maximum value for two layer fabrics increases to 23.92 as in Table 3.2. So this is an indicator of why protective clothing must be produced from multi-layer fabrics and not with single fabrics of high unit weight; because the air trapped in layers of fabrics is a good insulator.

Table 3.3 TPP test results of three layer fabrics

Fabric	Tolerance time (TT) (s)	TPP cal/ cm^2	TT (s)	TPP cal/ cm^2	TT (s)	TPP cal/ cm^2	TT (s)	TPP cal/ cm^2	TT (s)	TPP cal/cm^2
	Before Washing		1st Washing		3rd Washing		5th Washing		10th Washing	
1+6	15,46	30,92	14,86	29,72	15,4	30,8	14,73	29,46	16,53	33,06
2+6	17,4	34,8	17,73	35,46	17,23	34,46	17	34	19,13	38,26
4+6	14,35	28,7	15,5	31	13,37	26,74	13,75	27,5	14,7	29,4
3+6	12,86	25,72	15,03	30,06	15,43	30,86	14,76	29,52	16,83	33,66

In the test, whose results are in Table 3.3, the layered fabrics have greater thickness; and are heavier and bulky. Therefore it permits to obtain higher TPP ratings. The maximum TPP value is observed from again PBI/p-aramid sample and is 38.26 cal/cm^2. In NFPA 1971:1991 standard, the TPP rating required for a multi-layer fabric consisting of an outer layer, a thermal layer and a moisture layer is 35 cal/cm^2. Consequently, it seems that the TPP rating of 38.26 cal/cm^2 without moisture barrier is sufficient [6].

In this study, the influence of washing on TPP values was also evaluated. In TPP ratings of fabrics and fabric layers washed for various numbers of cycles, there is no fabric giving a value which is above the test repeating limit of ±2.5%. So that it can be said that repeated washing conditions have no effect on TPP ratings. However when examined separately, it can be seen that there is an increase in TPP ratings of some fabric samples. These results resemble measurements of Stull's study. Stull et al. (1996) recorded rises in TPP ratings after 25 washing cycles. They explain this rise as fluffing, increased thickness and thus increased insulation of fabric after washing cycles [11].

4. CONCLUSION

In this study, four different types of outer layer fabrics, one thermal barrier (inner liner quilted on aramid felt), and one inner liner were combined together to obtain a multi-layer construction. These constructions and each single-outer layer fabric are used to determine their TPP ratings. First, five samples of each fabric are washed for 1, 3, 5, and 10 times. Then, thermal protective performance (TPP) ratings are evaluated before washing (unwashed samples) and after certain washing cycles. The results are summarised below:

- Results of single layer fabrics before washing show that PBI/p-aramid and Nomex III fabrics provide the most protection. These high TPP values are due to the characteristics of fibres used to produce the fabrics and to thick, stiff char of Nomex III. Washing processes have no effects on TPP ratings. These values are in the tolerance limits of ±2.5%.

- The TPP ratings of two-layer structures are approximately 1.5-2.0 times of TPP ratings of single layer fabrics. Also, TPP values are generally increased by increasing number of washing cycles in two-layer structures. The cause of this may be the fluffing of structures occurred after repeated washing. Increase in TPP ratings of two-layer structures are more than that of single layer fabrics. The reason of this, besides air between fibres, is also the air entrapped between fabric layers.

- Among fabric variations used in TPP tests, the single layer fabrics have very low TPP ratings compared to two-layer (outer layer & inner liner) and three-layer (outer layer & thermal barrier & inner liner) structures. In three-layer structure, there is a bulky aramid felt. Therefore, the felt substantially increases the total thickness of layers and the amount of entrapped air, and so the highest TPP ratings are obtained.

REFERENCES

1. Mastura Raheel (Ed.), Protective Clothing Systems and Materials, Marcel Dekker, Inc., New York, 1994
2. Bajaj P. and Sengupta A. K., Protective Clothing, Textile Progress, Is. 2-3-4, V. 22, The Textile Institute, 1990
3. Jeffries, R., Clothing for Work and Protection, Lenzinger Berichte, Is.67, August 1989, pp.25-33
4. Laverty, G. (2001). Measuring The Performance Of Fabric Systems To Protect Against The Thermal Effects Of Electric Arcs. Laverty,G. (2001). Measuring the Performance of Fabric Systems Protect Against the Thermal Effects Of Electric Arcs. www.technica.net/NT/NT3/electricarcs.htm
5. Adanur, S. (Ed.) (1995). Wellington Sears Handbook of Industrial Textiles. Lancester: Wellington Sears Co.

6. NFPA 1971. (1991). American National Standard on Protective Clothing for Structural Fire Fighting-1991 Edition.
7. Stoll, A.M. & Chianta, A.M. (1969).Method and Rating System For Evaluation of Thermal Protection. Aerospace Medicine,40, Issue 11, 1232-1238.
8. Torvi, A.D.(1997) Heat Transfer in Thin Fibrous Materials Under High Heat Flux Conditions, Ph.D. Thesis, University of Alberta, Edmonton,Alberta.
9. Day, M. (1988) A Comparative Evaluation of Test Methods and Materials for thermal Protective Performance. In S.Z. Mansdorf, R. Sager, and A.P. Nielsen (Eds.), Performance of Protective Clothing: Second Symposium, ASTM STP 989,pp.108-120.
10. NFPA 1971. (1991). American National Standard on Protective Clothing for Structural Fire Fighting-1991 Edition.
11. Stull, J.O., Connor, M.& Heath, C. A.(1996). Development of a Combination Thermal and Chemical Protective Ensemble for U.S. Navy Fire Fighting Applications. In J. S. Johnson & S. Z. Mandsdorf (Eds.). Performance of Protective Clothing: Fifth Volume, ASTM STP 1237.

AN INVESTIGATION ON BREAKING MECHANISMS OF SOME SUTURES

A.S. Hockenberger, E.K. Bayraktar
University of Uludag, Department of Textile Engineering, Bursa

1. INTRODUCTION

Sutures that have been used for some 4000 years and have an important role in healing of wounds are the important medical technical textile materials used for every kind surgical procedures.
In a clean incised wound, the fundamental purpose of suture placement is to oppose the wound edges until the tissue is strong enough to withstand the normal tensile forces without mechanical support that is, until the healing process has progressed sufficiently. In order to choose the suitable suture for a surgical operation, it is necessary to know properties of sutures as material, structure and mechanical behaviour (1).
Breaking mechanism of a textile material after it has subjected to any load or deformation, plays an important role in determining its mechanical behaviour. Because, analysis of breaking mechanism is important to know the performance of material during the last usage, physical structure of material and breaking conditions affect the breaking mechanism (2, 3).
In this study, tensile tests have been made to determine breaking mechanism of sutures. In order to observe the effect of breaking conditions on breaking mechanism, sutures were used as without knot and with knotted. In this experiments, tensile strength and knot strength values have been obtained and observed different forms of breaking mechanisms. Tensile strength is defined as the measure of the amount of force enough to resist before suture will breake, when it subjected to load and divide by its size. Knot strength is the measure of the amount of force necessary to cause a knot to rupture and divide by suture size. When enough force is applied to a knotted suture to result in breakage, the site of disruption of suture is always the knot. Because, the force exerted on a knotted suture are converted into shear forces by the configuration of the knot and rupture the suture by increase the tensile. Therefore, mechanical properties of sutures in form knotted decrease and its fracture mechanisms differ (4, 5).

In order to determine the effect of suture structure on breaking mechanism, two synthetic sutures have been choosed in different structures:Monofilament and braided.Furthermore, tree different fineness for both of sutures.
After the tensile tests, pictures of broken suture ends have been taken in the Scanning Electron Microscope and Trinoculer Stereo Zoom Microscope for examining the detail breaking mechanism.

2. EXPERİMENTAL

2.1 Material

In this study two different types of sutures were used. Polyester and Polyamid stures were tested. Polyester suture was in the braid form and Polyamid suture was in monofilament form. Table.1 shows the properties of these sutures. Figures.1,2 shows the optical microscope of them.

Table 1. Properties of The Tested Sutures

Suture Material	Origin	Structure	Surface Prosedure	Size (USP)	Number (Tex)
Polyester	Synthetic	Braid	Silicon	0	119
				2/0	113
				3/0	54
Polyamide	Synthetic	Monofilament	None	0	132
				2/0	99
				3/0	51

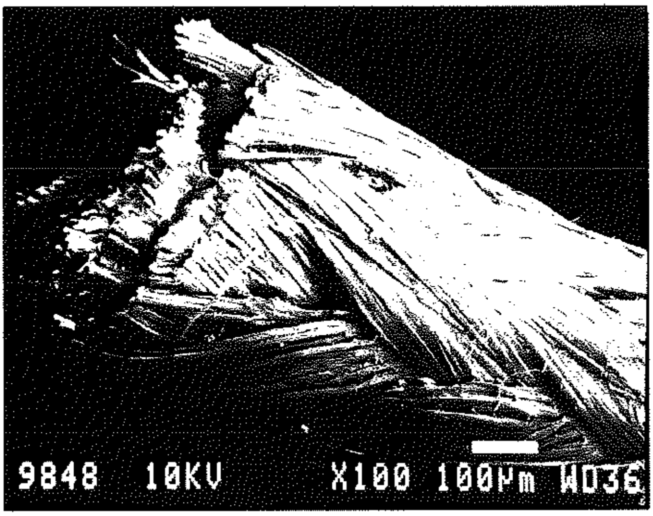


Figure 1. SEM View of Polyester Suture

Figure 2. SEM View of Polyamide Suture

2.2. Experimental Procedure

Instron 4301 Model Tensile tester was used in this study. The sutures were conditioned in atmospheric contitions for 24 hours perior to tests.
Sutures were tested in two forms to measure mechanical behaviour. Tensile tests were performed in straight form and the knot strength was carried out by putting a simple knot in the middle of the suture as shown in Figure.3. All the knots were applied to suture by means of 10 N of mechanical force. The gauge length was 8 cm and the cross-head speed was 20cm/min. Breaing mechanisms were analysed by using Jeol 840 Model Scanning Elektron Microskope. Optical microscopy analysis was carried out by Olympus SZ6045 Model, automatic Trinocüler Stereo Zoom Microskope.

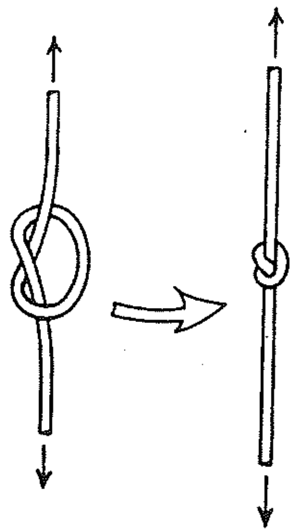


Figure 3. Schematic diagramm of the knot formation

3. RESULT AND DISCUSSION

3.1.Tensile Tests

Tensile results of the knot strength and the tensile strength are given in Table2 and Table.3

TABLE.2 Tensile Strength Results

Suture	USP	Max. Load (N)	Max. Tenacity (cN/Tex)	Max. Strain (%)	Modulus (cN/Tex)
Polyester	0	71,50 ± 1,28	60,08 ± 1,08	25,05 ± 1,44	334,12 ± 11,49
	2/0	54,66 ±0,24	48,37 ± 0,21	22,14 ± 0,43	326,52 ± 15,75
	3/0	23,46 ±1,51	43,46 ± 2,79	22,26 ± 1,30	266,77 ± 10,99
Polyamide	0	60,28 ± 1,14	45,87 ± 0,92	44,77 ± 2,82	176,57 ± 9,39
	2/0	43,99 ± 0,50	44,44 ± 0,51	36,17 ± 1,00	160,58 ± 4,61
	3/0	23,23 ± 0,49	45,48 ± 0,89	46,28 ± 3,11	173,84 ± 5,95

TABLE. 3 Knot Strength Results

Suture	USP	Max. Load (N)	Max. Tenacity. (cN/Tex)	Max. Strain (%)	Modulus (cN/Tex)
Polyester	0	31,52 ± 0,76	26,99 ± 2,51	13,73 ± 0,98	322,10 ± 18,17
	2/0	33,13 ± 1,22	29,32 ± 1,07	15,39 ± 0,46	326,48 ± 28,74
	3/0	14,52 ± 0,60	26,88 ± 1,11	10,92 ± 0,37	310,20 ± 11,82
Polyamide	0	37,54 ± 1,39	28,44 ± 1,06	23,90 ± 0,94	144,17 ± 4,49
	2/0	23,58 ± 2,31	23,81 ± 2,33	20,22 ± 1,97	140,81 ± 5,79
	3/0	15,09 ± 0,45	29,59 ± 0,89	22,31 ± 1,29	188,83 ± 10,34

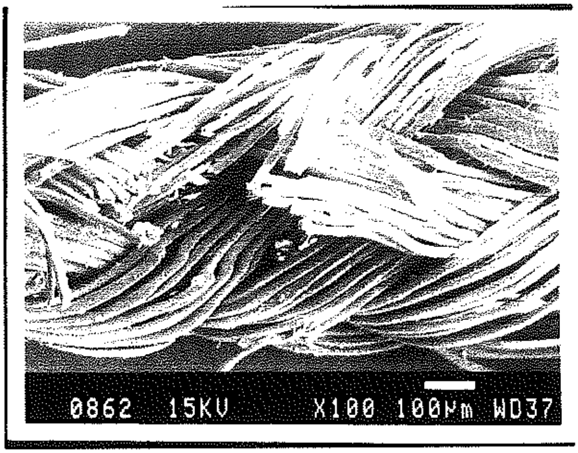
If a suture is loaded in a bent state, it will break more easily than when it is straight. This due to the initiation of breakage by the high extension of the outside layers. Therefore here knot strength values for both sutures are lower than tensile strength values. The biggest strength loss was recorded for the polyester size 0.

3.2 Optical Microscopy and SEM results

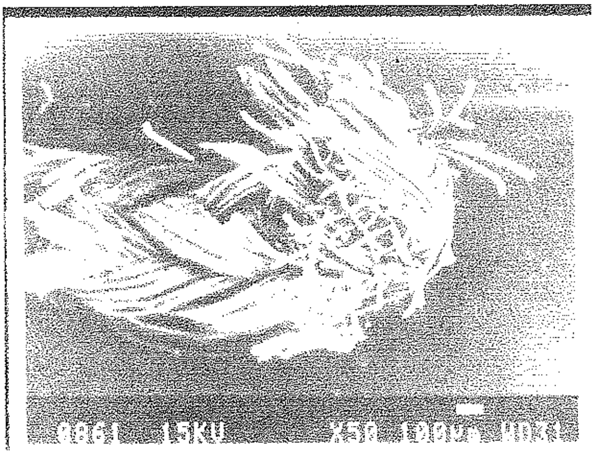
3.2.1 Polyester Suture

Sutures tested in Instron were analysed according to their broken ends and longititunal appearance. When knotted sutures analysed snap-backs until broken end were observed. The amount of these snap-backs was inreased when the thickness of the suture was deacreased. These snap-back regions were far away from the broken ends for the thickher sutures. However for the thinner sutures these regions were observed near the rupture . The diameter of the suture also was increased in these regions. Above these thicker regions a deacrease in diameter was recorded (Figure 4a). Upon this the suture had the normal diameter. The knot was openned (Figure 4b). Broken end had hooke form and splits. The amount of splits was reduced with deacreasing suture thickness.

The same pattern was also observed after analysis of breaking mechanisms of tensile tests. Only differeance was that here broken end had no hooke form and just had splits.



a

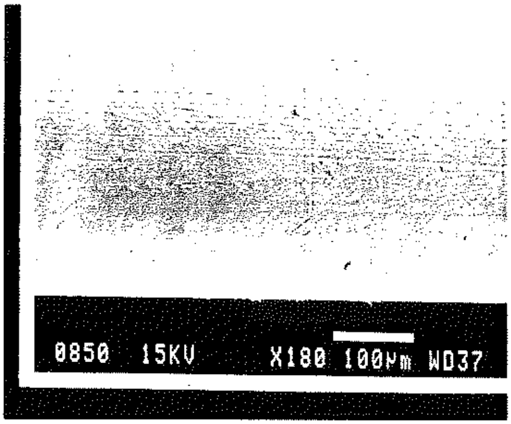


b

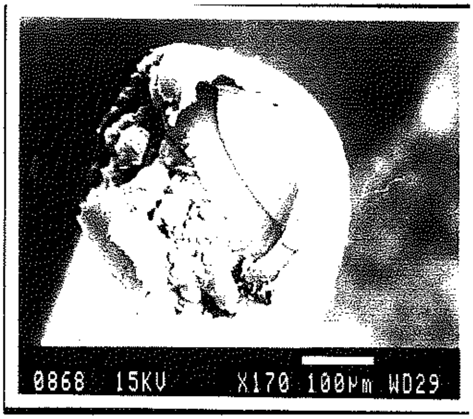
Figure 4. Polyester Suture

3.2.2 Polyamid Sutures

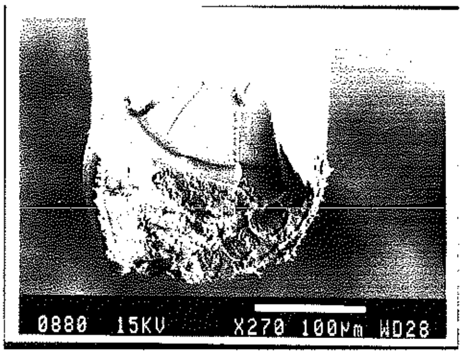
Polyamid sutures is in monofilament form. It was observed that the thickness of the sutures had no important effect on breaking mechanism for both straight and knotted sutures. The suture surface was even after breaking for both forms and the diameter of the suture remained almost constant along the suture length (Figure 5a). The knot was openned and a hooke form aws recorded at the broken end (Figure 5b). The snap-backs were very less for both forms independent of the suture thickness. At the broken ends typical ductile material behaviour was observed (Figure 5c).



a



b



c

Figure 5. Polyamide Suture

4. DISCUSSION

The type of material and the structure of the suture have a important effect on the sutures breaking mechanism. It was also observed that specially for the braid sutures the thickness of the suture has also a remarkable effect on the breaking mechanism.

REFERENCES

1-W. Van Winkle, C. Hastings, "Considerations the Choice of Suture Matwerial for Various Tissues", Surgery Gynecology&Obstetrics, 1972, 135(7), 113-126.
2-A. Şengönül, "Tekstil Liflerinin Kopma Mekanizmaları", Tekstil Maraton, 1996, 6(6), 19-30.
3-J.W.S. Hearle, B. Lomas, W.D. Cooke, I.J. Duerdon, "Single Fibre Failure", Fibre Failure and Wear of Materials, 1989, Ellishor Wood Lmt., England, 11-19.
4-J.G. Thacker, G. Rodeheaver, J.W. Moore, J.J: Kauzlarich, L. Kurtz, M.T. Edgerton, R.F. Edlich, "Mechanical Performance of Surgical Sutures", The American Journal of Surgery, 1975, 130(9), 374-380.
5-R.L. Moy, B. Waldman, D.W. Hein, "A Review of Sutures and Suturing Techniques", J Dermatol Surg Oncol, 1992, 18, 785-795.

AN EXPERIMENTAL STUDY ON THE BUOYANCY MATERIAL USED FOR MANUFACTURING OF MILITARY BOATS

D. Toprakkaya
Textile Engineering Department The University of Uludag, Bursa

ABSTRACT

The aim of this study is to determine the changes in the values of specifications ruled by AVON under severe conditions exposed during military usage. This study covers the experiments done on the hypalon coated fabric(Nylon 6,6) which is used to manufacture military boats which may be powered by diesel engine.

1.INTRODUCTION

It is important to know the behaviour, in actual conditions of usage, of a buoyancy material as well as that of in laboratory conditions. This is because of different geographic conditions. The climatic conditions also bear differences at different regions even in the same country, so that is why it is needed to test a buoyancy material in actual conditions. This means it is necessary to know the test values of the material to be used for manufacturing the military inflatable boats since there would be other factors to be thought during a tactical movement where there heavy and oil-like logistic materials might be carried which can highly influence the boyancy material.

The materials generally used for all inflatable boats are composed of fabric coated on both sides with reinforcement products to create a material with several layers, as follows:

Outer Layer: This layer must be a highly resistant and tough layer that will protect the boat against the elements and abrasions. It is important that this layer will resist the ultraviolet(UV) sun rays as well as gasoline products, water, atmospheric pollutants and temperature variations. The two most important products used on the market are Hypalon®, the registered trade name for a Du Pont patented product, and polyvinyl chloride commonly known as PVC.

Middle Layer: The strenght of the boat is in this layer which comprises a heavy woven fabric of either polyester or nylon. Polyester is more expensive and will stretch significantly less than nylon and with better memory. This maintains a rigid shape which especially important for the role bottom floor.

Inner Layer: This layer is to ensure the boat remains air-tight and that the seams are well bonded. The products used are neoprene, Hypalon or PVC.

The weight of the fabric comprising all layers is also important. A higher weight will provide a stronger tube and longer life for boat. [3]

COATING COMPOUND

The coating compound necessarily includes the base elastomer, HYPALON, chlorosulphonated polyethylene.

What is HYPALON and Why HYPALON.

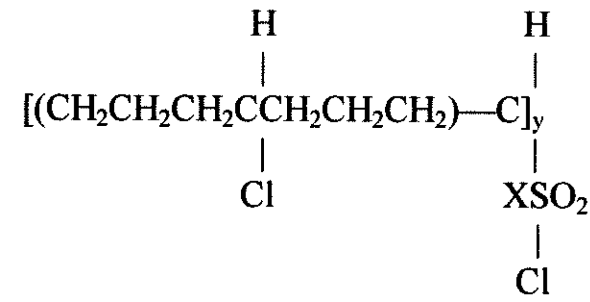
Hypalon, a synthetic rubber, was introduced to the rubber industry in 1952 by E.I.Du PONT de Nemours and Company. It was first manufactured at Beaumont, Texas.

Hypalon are made by the chlorosulphonation of polyethylene.

Crystalline polyethylene is converted to an amorphous elastomer by the introduction of chlorine in varying amount which may go as high as 45%.

The resulting polymers are responsive to a variety of curing systems which react to the presence of a small number of sulphony chloride junctions or relative alkyl chloride structures.

This is illustrated in the following schematic chemical structure where in the value of x is approximately 12 and the value of y is approximately 17.



There are six types of hypalon currently available designed HYPALON 20, 30, 40, 4085, 45 and 48. The polymer (all types of hypalon) are extremely stable chemically. Hypalon 45 and 48 are more thermoplastic than others. Upon milling, all types soften and mass readily. Hypalon 20 and 30 readily dissolve in aromatic and blended solvents(toluene alone or with selected ketons) and require no special preparation.

Hypalon vulcanizates are characterized particularly by outstanding resistance to ozone attack and color retention during light exposure.

Hypalon products have excellent flame and oil resistance. In addition these products are further characterized by excellent heat, weather, chemical and abrasion resistance. The general physical properties of hypalon vulcanizates change from good to excellent according to convantional rubber standards.

Specific examples of utilization of the properties of hypalone include elecrical products, hose, belting, automotive parts, white sidewall tires, building products and coated fabrics.

Fabrics with an attractive coating of hypalon are weather oil-, flame- and water-resistant, rugged, lightweight and easy to handle. Truck tarpaulins of hypalon-coated nylon and colorful hypalon-coated fabrics used to manufacture inflatable boats are widely used in extreme conditions. [4]

2. EXPERIMENTAL

2.1 Material

The buoyancy material obtained for this study is still used to manufacture military boats in a military plant. Material properties are given below:
Table 1. Material properties

Material	Nylon 6.6
Coating Compound	Hypalon
Yarn Count	950 dtex
Weaving Type	2x2 plain
Weight	284±10 g/m^2
Construction	Ends/100 mm 140±5 Picks/100 mm 145±5
Tensile Strenght,min	Warp Kg/50 mm 420 Weft Kg/50 mm 420

2.2 Method

The boyancy material has been cured at 148°C for 45 minutes and then tested for the properties given by the requirements. In addition to tensile testing was applied to the specimens after exposing heat aging, artificial weathering, oil immersion, sea water, cold media and ozone aging to sea to observe the change in physical condition of material.

Table 2. The results of the tests ordered by requirements

	REQUIRED VALUES (BY AVON)	TEST METHOD	TEST VALUES FOUND
1. tensile strenght minumum. Kg/18 mm	Warp 122 Weft 120	BS 3424 Const. Cate of ext.Machine Federal St. 4001	134 131
2. Heat Aging 7 days at 70°C	No cracking, blistering, stickness or brittlenes	Federal Standard 7001	No cracking, blistering, stickness or brittlenes.
3. Artificial weathering XENON Arc Lamp. 48 hours at 42°C black panel temperature	No cracking, blistering, stickness or brittlenes	TS 4460	No cracking, blistering, stickness or brittlenes
4. Oil resistance 72 hours in ASTM No 1 oil (SAE 50) at 70°C	Swelling must not exceed 15%	BS 903	8.85%
5. Resistance to cold crack 24 hours at -20°C	No cracking when viewed	Federal St. 5111	No cracking was observed
6. Ozone resistance 32 hours at 40°C in MAST -700-1 machine	No cracking	TS 1773 ASTM D 3041	No cracking was observed

As it is seen from the test values obtained experimentally, the buoyancy material ensures the requirements.

The results of the tensile tests additionally where the material was exposed to different outhern effective conditions are below:

Table 3.Effect of chemicals (24 hours at room temperature)

CHEMİCALS	% CHANGE IN TENSILE STRENGHT	%CHANGE IN ULTIMATE ELONGATION
HCl, 10% (w/w)	-0.43	-0.84
HCl, 20% (w/w)	-7.49	-7.28
NaOH, 10%	-7.42	-7.69
NaOH,20%	-22.72	-22.19
H_2SO_4,10%	4.1	-3.6
H_2SO_4,20%	5.44	-7.65
ASTM #1 oil	-9.19	-2.72
Sea Water	0.61	-9.03

Table 4. Effect of different conditions

	% CHANGE IN TENSILE STRENGHT	%CHANGE IN ULTIMATE ELONGATION
1.Effect of ozone	-17.2	17.56
2.Aging -Aging at 105°C for 24 hours -Aging at 70°C for 7x24hours	 -4.59 -11.21	 -5.86 -11.29
3. Resistance to cold at -20°C for 24 hours	3.14	-1.34

3. DISCUSSION

It is well known that Hypalon is used in rubber industry because of its wide range of uniqe properties which may be summarized as;

- Permanent bright colors
- Superb ozone and weather resistance
- Heat resistance to 150 °C

- Resistance to wide range of strong chemicals
- Intermediate oil and solvent resistance depending on the chlorine level
- Electrical insulating properties

Some of the above properties have been subject to this experiment to express the changes in the tensile properties since there may be not any theoretical and experimental values in standard reqirements.

1. Effects of Chemicals

It is expected that hypalon can resist wide range of strong chemicals.

In the experiment, HCl and NaOH had effected the material from moderate to severe levels depending on the concentration. NaOH having a concentration of 20% (w/w) resulted a decrease in tensile strenght and ultimate elongation of 22% that is to say that NaOH may cause to harden the elastomer. For HCl it can also be said that the case is the same. H2SO4 show little effect on the tensile properties of the material. It has been observed that the oil (ASTM #1) has the same effect of hardening due to decrease in tensile strenght and ultimate elongation. On the contrary it is expected to cause to soften where it is estimated to decrease in tensile strenght but increase in ultimate elongation.

2. Effect of Ozone

The cracking on the surface was not observed after the experiment done according to ASTM D 3041.

Although hypalon is stated to have superb ozone resistance as it is expected but in this experiment the tensile strenght and ultimate elongation of the material have shown a remarkable decrease after ozone attacking.

This remarkable decrease (17% in tensile strenght and ultimate elongation) may be due to hardening of the material which may be resulted by ozone attacking to the saturated backbone of hypalone.

3. Heat Aging

The superior heat resistance of hypalone is said to be a unique property. In this experiment heat aging applied for 7x24 hours at 105°C caused a decrease in tensile properties of the material as a value of 11% which may again be resulted due to hardening. This conclusion is logical because elastomeric materials generally exhibit the same behavior when exposed to heat and it is necessarily expected to have a decrease in tensile values after aging.

REFERENCES

1. Producers Document (AVON), Issue 13, 19.12.1997, Spec.Ref.01/01/50
2. Tecnical Information. www.dupont-dow.com
3. http://www.houseboatmagazine.com/articles.cfm/artid/247.
4. 'Rubber Handbook', R.T.Vanderbilt Co.Inc., USA,1978.

REVIEWS ON WEARABLE COMPUTERS

E. Yazgan Bulgun. , S. Yeşilpınar, O.Kayacan
Dokuz Eylul University, Faculty of Engineering, Textile Eng. Dep.,İzmir

ABSTRACT
Recent developments in computer technology have affected not only the high technology industrial fields but also the textile and the clothing industries. Beside the integration of clothing machinery with computers in many ways, the clothing products for IT industry were developed. Since early 1990's, computer aided equipments and microchips have been integrated in to the clothing products, which are utilized in military, health, security and communication industries. In this paper, the products called smart clothes-wearable computers and related fabrics, which are predicted to be a part of our daily life, have been introduced.

1. INTRODUCTION

The semiconductor technology and advances in computer industry make it possible to place the computer devices in less space and to work in higher speed. Also it allows inputting data by using speech and gesturing. Combined with mobile communication technology, users can access information anywhere. The development of mobile computing made it possible to carry a personal computer device in a brief case or a pocket. They are treated as a small computer that allows user to provide the same range of input and output devices as on a desktop and to perform the same applications. Wearable computers merge the user's information space with his/her workspace. Although wearable computers should offer unfixed interaction in the existing working environment, conventional methods include the keyboard, mouse, joystick and monitor that require some fixed relationships and they reduce the efficiency of the wearable systems. So that wearable computers should provide freedom and the ability to the users to work in a real mobile environment [1].

On the other hand, wearable computer systems are computer information studies, which are designed to improve employee performance. For instance, wearable performance support systems seem to be most benefit to a user when the tasks to be performed are very complex or the environment in which the user must operate prohibits the use of standard materials such as operating manuals. Also these systems can improve the speed and quality of learning by providing the right information when and where it is needed [9].

As the world of electronics and telecommunications takes hold of our lives in the 21st century, our clothing too will be greatly influenced by it. Clothing in the future will not only keep us cool and warm as required, but will have the "intelligence" to warn us of environmental influences and dangers, keep us from harm, monitor our health conditions, heal our bodies, give us a feel of well-being, determine our positions when we are lost, find what we are looking for, and enable us to communicate with others even when we are physically unable to do so [9].

Wearable computer applications are currently being developed also for a number of military applications. Also, supporting the medical staff is another field. The system allows the medic to enter data concerning the condition of the patient in to an electronic record using voice input. This critical data can be accessed to the final treatment facility by using a wireless network. Moreover, one of the other wearable computer application focuses on minimizing the time and personnel required to conduct a routine inspection and maintenance of a piece of equipment. Advantages include less formal training requirements, enhanced accuracy of data collection, a reduction in inspection time and a simpler method of updating and maintaining the required procedures [8].

In the literature review, performed within this study, it was seen that, there are several wearable computer applications developed by different universities, institutes and commercial organizations. But in this paper, some of the recently developed textile and apparel products such as intelligent wears and fabrics are only presented.

2. EXAMPLE STUDIES

2.1 New Fabrics

Nonwovens mostly regarded as textiles for hygiene products, interlining and medical usage products, are making a break-through in clothing.

- Fraudenberg's Evolon nonwoven fabric is a microfibre of 0,01 dtex nylon and polyester, washable, draping and tear resistant. It is aimed at the outdoor sports outwear market. It comes in a napped, sanded, peach skin or suede finish or is soft, wrinkle-resistant and with moisture- management properties. Its cross-section is very much like that of our skin, thus transporting moisture away from the body. The UV protection is not affected by washing. It is breathable, also an effective wind-blocker. It is extremely lightweight at 100-120 g/m, offering the same thermo factor as 200 g/m woven fabric, but 30 % warmer and 40 % lighter [9].

• Polymer Group Inc. presented Miratex fabrics, using their Apex technology. These nonwoven fabrics for garments look very like knits and woven. They are produced from virgin or recycled fibers of cotton, polyester, nylon, rayon, kevlar, nomex. Any fabric structure can be laser scanned and the Apex imaging system directs the hydro entanglement process to mimic and create the same pattern structure. Fabrics made with this technology look heavy but feel light [9].

• Gore Technologies presented a unique combination of thermal protection and liquid barrier for airy outwear, and of Goretex Antistatic protection for work-wear using nanotechnology. They displayed many new products developed with many technologies–membranes, Laminate, cabling and termination, signal integrity and EMC know-how, filtration and ventilation. Others interesting such as Gore-tex s-key – ski pass are built in to the gloves, Goretex leather laminate is breathable yet water resistant, Goretex XCR and Paclite are innovations in functional clothing. Goretex wind stopper controls heat loss. Goretex electro-textile can be adapted for computer keyboard use in fabrics with sensors in the gel [9].

• One of Textile Research Institute Thüringen-Vogtlnd's latest developments is the 3D spacer fabric. The specific properties of these 3D structures, such as breathable, moisture elimination, insulation, pressure elasticity and clothing-physiological ease are especially effective in a textile worn next to the skin [9].

• Swiss Shield produces an EMC yarn that contains a highly conductive fine silver plated metal core that can be coated with a lacquer (insulated surface) or with a silver alloy (for insulation or conductivity). Fabric woven or knitted with this yarn offers excellent shield efficiency or conductivity, depending on the application. Lightweight, washable, transparent and flexible, durable, flame-retardant and water and dirt resistant [9].

• The newest product of Rotta, a textile finishing company, is their ever fresh Breeze, which can absorb and store unpleasant odors and be washed away, also slowly release pre-stored scent, thus keeping textile fresh longer. It also has a antimicrobial effect [9].

• New plasma finishing process of Dankendorf Institute changes the surface properties of the fabric from hydrophilic to hydrophobic, providing water and oil repellency at low cost.

- Centexbel, the research lab of Belgium, has solar cells that can be sewn on the garment or the tents. It is a coating on stainless cell to power the equipment you carry [9].
- Meida's 100 % polypropylene is extremely thin and soft insulation, great for all clothing types yet is an excellent wind barrier. One layer of Meida is equivalent to three sweaters; it is even machine-washable [9].

2.2 Levi's-ICD (Industrial Clothing Division)

Levis, in conjunction with Philips, has created a range of clothing that represents both the latest in functional work-wear and state-of-the-art technology. This new range of clothing will provide consumers with apparel that combines garment functionality with modern communication-wearable electronics or intelligent wear (i-wear) [4].

For Philips, originator of the idea of wearable electronics in 1995 and creator of the technology behind Levi's-ICD, the launch realizes for the first time the concrete possibility of merging a traditional technology focused industry with the world of fashion. The product, named Levi's-ICD, will offer pioneering modern work-wear that will utilize up-to-date technology. There will also be a more commercial range of clothing Levi's-ICD with a wider distribution [4].

The Levi's-ICD range has been designed for people who want to control their life and their living environment. They demand maximum freedom, mobility and flexibility from their apparel. These users also expect iconic design and style with functionality and performance.

Each of the Levi's-ICD products is based on three key criteria.

- Modularity
- Protection
- Connection

The i-wear range sees the merging of function, fashion and technology; diverse areas now converging to provide relevant clothing for a specific, pioneering target audience [4].

Levi's-ICD is a range of for jackets, which includes a producer's jacket featuring an integrated communication and entertainment system. This consists of a Philips MP3 Player and a Philips Xenium GSM (General System of Mobile Communication) Phone, controlled by a unified Remote Control Unit. Voice dial can be operated via a microphone inserted in the collar and both music and phone calls can be listened to via ear gear [4].

The overall package is an exciting combination of outstanding functional technology. The models, named **Beetle, Mooring, Producer, Trc, Courier and Cagoon**, were produced from Levi's Company. Courier and Cagoon models are shown on Figure 1 and Figure 2.

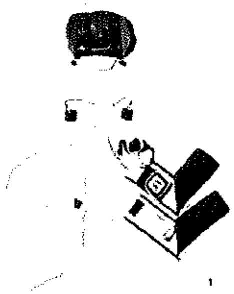


Figure 1. Cagoon Jackets

Figure 2. Courier Jackets

Beetle, Mooring, Courier and Cagoon jackets are made of a fabric that is breathable, temperature regulating, metalic coated and water repellant. 90 % Polyamid and 10 % Polyurethane are the ratio of the fabric components of these models [4].

Trc and Producers types are consists of 100 % Polyester and 100 % Polyamid in order. These jackets also can be machine washable. Philips mobile phone and MP3 player can be integrated in to all models [4].

The system is provided with a unified remote control unit. This unit offers control to the paramount functions of the connected devices while being mobile. It allows the user to play back music, make and receive calls and even play music down the phone [4].

2.3 Dockers Mobile Pant

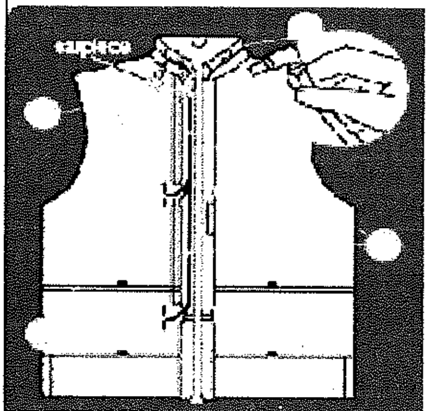
Mobile Pant is the one of the latest models of Dockers. It has 2 'Hidden Zip Vault Pocket'. Secretly located within the front mesh pockets is the hidden zip vault pocket that keeps valuables like keys and loose change in place. This additional zip pocket allows the user to separate his belongings so he can always put his fingers on what he needs. The Dockers Mobile Pant was designed to carry the weight in user's pocket without weakening the waist closure. Highly reinforced zipper and a hook & eye closure ensure the connection in more ways than one. Mobile Pant has 'Stowaway Seam Pocket' on both sides. They constructed at the thigh, ensures that user's pockets never become overloaded. So not only can this pant carry a surprising number of gadgets but it can conceal the pockets and their contents as well. A strong hem finishes off the clean style of this no-wrinkle pant. Double stitched for long lasting durability, the hem of the Dockers Mobile Pant represents quality is the final detail. Khaki and black are the colors of this wrinkle-free pleated product. Consequently, it is available on 30-44 sizes [2].

2.4 Scott-e-Vest Jacket

The Scott-e-Vest jacket is a vest and a jacket in one product that packed with features to ease user's life. It has 17 ergonomically designed pockets to safely store all the gadgets and other gear. It has easy to open pockets for fast access to a cell phone or PDA (Personal Digital Assistant) and a clip for securing the keys. Totally it includes 17 pockets, including patent-pending PIP's (Pocket-in-Pocket) with a large pocket in back of jacket. Also there are two large interior pockets with Velcro closures and access to Technology Enabled Clothing system, so user can network his/her devices. Two patent-pending Pocket-in-Pockets in the large exterior pockets can keep user devices from hitting each other. Also secret interior zipper pockets can be used for money, smaller disks, I.D.'s. Larger electronic devices such as CD players, camcorders and portable keyboards - even big enough for beverage containers can be placed in to two large hand pockets. Two side-opening breast pockets make it easy to grab the cell phone/PDA. Side pockets also connect to the large top-opening pockets, which can accommodate a whole host of other devices. Two small exterior zipper pockets are ideal for business cards, change or anything the user wants to keep safe. Mesh-lined interior pockets help the user keep track of his/her change, sunglasses, keys, or anything else they want to see. Pockets were designed to protect the devices and also allow the user to feel the vibration of cell phones [6].

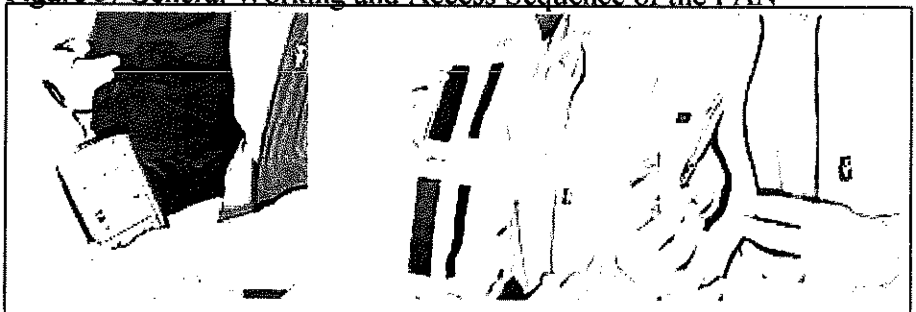
The Scott-e-Vest jacket is loaded with great features that help user to be truly mobile. It can liberate user from dangling wires, and store all of the gadgets and stuff in the many pockets. It could create user's own "Personal Area Network". The Scott-e-Vest jacket is designed to be used with most electronic devices, but does not include any electronic equipment or wiring. The Scott-e-Vest jacket is a great solution to the new airport security procedures for the travelers, who take their gadgets often. They should just take off the vest and put it through the x-ray machine. No need to take things off the belt, out of pants or pockets etc. Clothing features are technology enabled. Personal Area Network (PAN) with double Velcro flap closures cover conduits connecting devices from pocket to pocket. It's possible to wire devices through the lining of the Scott-e-Vest jacket. There are four hidden collar loops that hold the ear buds and/or headphones. The Scott-e-Vest jacket allows using electronic gadgets (phone, PDA, etc.) while wearing and the devices can be recharged while devices are in the Scott-e-Vest jacket. Lightweight, water-repellent all-season fabric with removable zip-off sleeves makes it versatile. Reinforced armholes, adjustable waists tabs and bar tacked at every stress point, are the other features. Mesh-lined back and neck area for keeps the user cool and dry [6].

Figure 3 shows how the PAN works and Figure 4 shows the PAN that allows connecting Pocket-PC/PDA to the user's cell phone to surf the Internet and retrieve the e-mails. Also the PAN is completely hidden from the exterior. The PAN ensures the easiest and quickest access to the cell phone and/or PDA. There is not one correct way to connect the devices using the Personal Area Network (PAN). Most pockets are connected to the PAN, so cell phone, PDA, or other devices can be put in almost any pocket.



1. To access the Personal Area Network, open the Velcro on the interior of the vest.
2. Insert the 'male' end of the wire through the loop near the neck area (on the same side of the vest where the device is located).
3. Run the wire through the conduit to the pocket where the device is located.
4. Punch the wire through the access hole and attach it to your device.
5. If you're using the Personal Area Network for a hands-free device, the microphone should be placed through the loop near the collar.

Figure 3. General Working and Access Sequence of the PAN



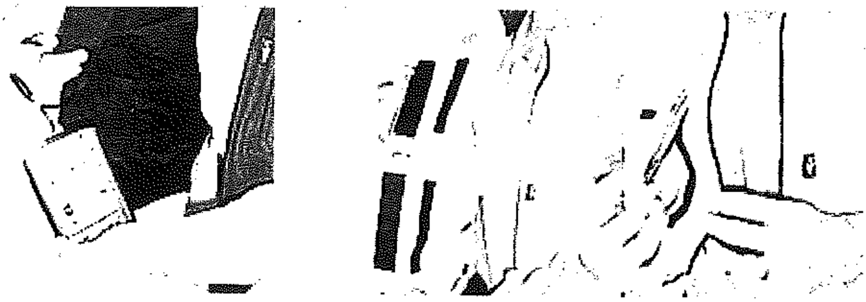


Figure 4. The PAN (Personal Area Network) Connections in Scott-e-Vest Jacket

2.5 Sanyo Coat with Multi-Function Pocket System

A leading provider of handheld computers and Sanyo Fashion House, a subsidiary of Sanyo Shokai Tokyo, one of the largest international apparel manufacturers in Japan, have collaborated to create a new handheld-ready line of spring raincoats with a "Designed for Palm Handhelds" pocket. These luxurious raincoats, complete with a Palm logo button securing the pocket, are made for both men and women. Fashion conscious consumers can use the specially designed interior pocket of Sanyo's coats to securely store and easily access their Palm handhelds. Figure 5 shows the details of multi function pocket system [5].

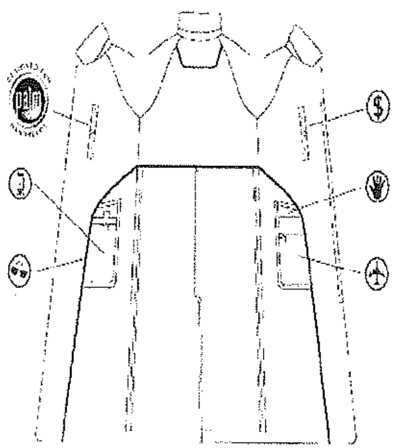


Figure 5. Inside detail of a Sanyo coat with Multi-Function Pocket System

Specially designed pocket increases Palm handheld wearability. All the new Sanyo coats contain one or more of the pockets, which are shown on the Table 1.

Table 1. Pocket Types

	Special pocket design for palm device * Lined with static shielded material		Ticket & passport pocket *zipper closure
	Wallet & money pocket *with extra secure closure		Glove & scarf pocket *large with easy access
	Cell phone pocket *lined with anti-magnetic material		Sunglasses pocket *for the essential accessory

Palm's design philosophy compels the products to be not only functional, but also fashionable and wearable. Sanyo's raincoats exemplify these characteristics by providing Palm handheld users with a stylish new way to carry their handhelds. After extensive market research, Sanyo has identified that its customers are often Palm handheld users who need a pocket with greater security and accessibility. The pocket uses a static shield lining material, waterproof liner and a laser engraved Palm logo button closure. Prices range from $185 to $695 at fine specialty stores nationwide. The Fall 2001 Collection also featured coats with a pocket designed for Palm handhelds [5].

2.6 The Bristol Wearable Computer Project

The Bristol Wearable Computing Project is concerned with exploring the potential of computer devices that are as unconsciously portable and as personal as clothes or jewellery. The project was set up in Bristol, England at the start of 1997 as collaboration between the Computer Science Department of the University of Bristol and the Hewlett-Packard Research Laboratories, Europe. Together, a suite of programs have been developed which use context sensing devices to enable the right information to be delivered to the user of the jackets at the right time and in the right place. There are 3 kinds of products, named CyberJacket, BlazerJet and e-Gilet. CyberJacket is shown on Figure 6, is equipped with a CardPC, dGPS (Differential Global Positioning System) and GSM (Global System for Mobile Communications) phone and the user interface is audio (speech recognition) and/or a handheld display. For the busy man (or woman) about town, BlazerJet, shown on Figure 7, is equipped with CardPC, GPS, GSM phone, a novel receiver and both the audio interface and a handheld PC. e-Gilet is the first step into the world of fashion. A French connection gilet fitted with the demonstration rig - a CardPC, and handheld PC [7].



Figure 6. CyberJacket Figure 7. BlazerJet Figure 8. e-Gilet

2.7 Elektro-Textiles (Elek-Tex)

Elek-Tex has been evolved by the Elek-Sen Company, which researches, develops and licenses interactive soft switching solutions for innovative product opportunities [3].

Elek-Tex is fabric based, has a thin profile, conforms to irregular curved surfaces and is lightweight. It's portable, versatile, durable and cost-effective, enabling a new generation of consumer products with soft, flexible and lightweight interfaces and combines conductive fabric structures with microchip technology as an intelligent fabric. It ranges in size from 2 cm to 2 meters. Elek-Tex looks and feels like a fabric, but it's more than that. Using in wire-free soft technology, It's an intelligent technology capable of electronic sensing, heralding a new generation of product opportunities. Also, according to the needs, it can be folded, scrunched or wrapped [3].

Elek-Tex can sense on three axes (X, Y and Z) within a textile fabric structure approximately 1 mm thick. The technology is a combination of the Elek-Tex fabric sensor and the Elek-Tex electronic and software systems. The resulting fabric interfaces deliver data according to the requirements of the licensee. The three modes of Elek-Tex sensor operation - position sensing (X-Y positioning), pressure measurement (Z sensing) and switch arrays - are normally achieved through four connections to each fabric interfaces. Elek-Tex maintains the durability and resilience of textiles, and has been developed using existing conductive fibers and looms in order to speed its introduction in manufacturing. The system works even if the fabric is folded, draped or stretched. The resolution of the fabric is high, capable of inputting to electronics up to 10 bit [3].

When it comes to the physical properties of Elek-Tex, it is as durable and resilient as other textiles. Applying some tests such as durability testing of the soft textile prototypes, the press test, the tumble test, the folding test, has proved it. After performing the tests, it's been observed that there are no sign of failure and all parts work properly. The main application areas are telecommunication, computer technology, automotive interior design and healthcare industry. Elek-Tex can be used in researches about telematics, SMS (Short Message Services) messages and smart phones field and offers the opportunity for radical telecoms product designs today. Figure 9 shows some of these products [3].

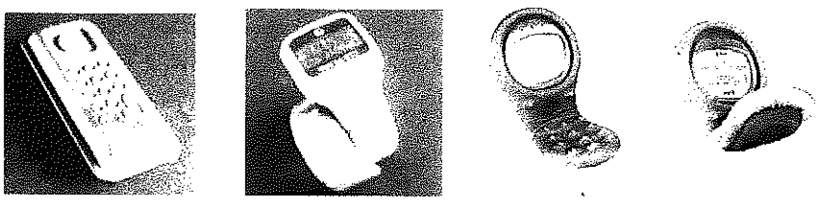


Figure 9. Elek-Tex Products

On the other hand the KeyCase, the first commercial product featuring Elek-Tex technology, is a soft and durable fully-featured keyboard that doubles up as a stylish case, protecting your Palm handheld wherever you go. Elek-Tex offers the opportunity for radical product designs for vehicle interiors today and also healthcare product design is another field of application [3].

3. CONCLUSION

Smart and intelligent clothing is one of the most innovative concepts. Tomorrows clothing should warn us of environmental influences and dangers and analyze them and act accordingly and should be able to recognize moods,. Future clothing will involve microsystems, microelectronic, micro-optic, micro-mechanic and biocomponent. They can locate objects or people; measure things receive and transmit information, generate and manage energies. They will be made of smart materials with memory. A smart T-shirt will indicate where the wearer is located and contain a radio and a mobile phone [9].
Smart clothing is most useful in search and rescue operations as in avalanches. A sensor in the bed sheet will help monitor the progress of the patient in the hospital or of the elderly in their homes. It can improve health by continuously measuring

the glucose in the body, so that the right amount of insulin can be pumped in to the body. It can monitor the body's condition and adjust to the environment [9].
Clothes that can keep the body cool, as well as warm jackets with heating coils; audio-jackets etc. are some new ideas for clothing for the future. Developing a high-tech clothing industry in Europe is being supported. Traditional clothing production has been already shifted to lower cost countries.
In the future; the clothes, which have the following functions, will be a part of our daily life [9]:

- In the business and net wear field; a mobile office in clothing with mobile phone, G.P.S. integration, dial pad on the sleeves, memory vest, microphone and recorder to record and recall what we see and hear.
- In the security and protection field; transponder for S.O.S., pathfinder in the snow, flashing reflector stripes for safety in the dark, geographic locator.
- In the health and anti stress field; an electromagnetic shield in our clothes or home textiles to block disturbance that causes headache, depression, cancer etc.
- Solar jackets, memory vests, safety garments that light up in the dark.

Intelligent clothing must be understood to be fully utilized. In the future, intelligent devices such as sensors, computers and mobile phones can be part of our clothing. But the regular washing, ironing and ordinary wear withstanding of these cloths, probable emitting the harmful substances owing to so close existence of the microchips to the bodies and the reactions of the consumers in case of the carrying such a device, will be the main subjects of future studies [9].

REFERENCES

1. http://www-2.cs.cmu.edu/afs/, 22 May 2002
2. http://www.dockers.com/mobilesitelet/flash/mobilepantflashtest.html, 29 May 2002
3. http://www.electrotextiles.com, 28 May 2002
4. http://www.levis-icd.com, 22 May 2002
5. http://www.sanyofashionhouse.com/pocketsystem.html, 04 June 2002
6. http://www.scottevest.com, 31 May 2002
7. http://wearables.cs.bris.ac.uk, 06 June 2002
8. http://wearables.gatech.edu/EPSS.asp, 07 June 2002
9. Sung, V., 2000, Textile Asia, Volume:31, No:12, pp. 19-22

NONWOVEN GEOTEXTILES

M.C. Kütükoğlu
Hassan Tekstil A.Ş., İstanbul

ABSTRACT

Geotextiles that are used in the past fifty years every year in greater quantities are not only an indispensable material for the construction sector but they are also a successful member of the technical textiles which are used in the construction and structure sector.

This text includes the production stages and techniques, kinds, raw material (chemical and physical characteristics of the raw materials as well as the reflection of these characteristics on the final product), functions and application purposes of the geotextiles as well as the details where they are used in the construction and structure sector, the points to be considered during the choise among them and at the areas where they are used, the economical and technical majorities they have, their resistance against outside effects; furthermore, use purpose, functions and advantages of the geotextiles in the information and regarding details on the important projects where the nonwoven geotextiles that we as HASSAN TEKSTİL AŞ have produced, are used.

Description And Classification Of The Geotextiles

Geotextiles which are described in the American Standards (ASTM-American Society of testing and materials) as "permeable textile product used together with any material regarding the basic element as a part of a project, structure or system designed by human or, ground, rock or earth or, for geotechnical engineering", are permeable covers produced from synthetic raw materials like polyester, polypropylene, polyethylene.

Essentially the geotextiles are classified in two main groups:

- nonwoven geotextiles
- woven geotextiles

Here, we will talk about the nonwoven geotextiles that are subject of the main production.

Nonwoven geotextiles:

They are geotextiles produced without using the sewing process and used in the wool industry, the fibres of which are ordered in a certain direction or at random and bound mechanically, chemically and physically.

Production Methods

i) The method where the production is made by needle punching:
The cut fibres are prepared and then the blend is prepared under consideration of the chemical structure, length, thickness and twist feature of the fibres. This blend that has been prepared is sprayed with chemical substances in order to increase the electrification and rubbing. And then the fibres are transferred to the comb unit for the combing process. This structure formed, is folded one right after the other by using a mechanism named spreader. The swollen fine muslin layer is drawn through two drums and it is needled according to the thickness of the fine muslin layer made from unbound fibres. During the needling process, a part of the fibres and filaments goes upward being attached to the needles and a part remains at its original place. The fibres are pulled downward with the repeated needle penetration, and so the fibres are bound mechanically to each other. The thickness of the cover decreases after the needling process.

Each needle table consists of a great quantity of needle points. Weight per unit volume and density of the nonwoven geotextile depend on the number of the needles. Furthermore, the mechanical and hydraulic characteristics of the nonwoven geotextile depend on some parameters like the type of the fibre raw material, the physical characteristics of the fibres (denier, length, crimp etc.), needling rate, and machine speed. As a result of the flexibility of the bonds of the nonwoven geotextile which is achieved through needling, the deformation energy is relative high.

ii) The method where the production is made by uniting through melting:
Obtaining a nonwoven with this method: The fibres forming the product, are in form of a thermoplastic polymer granule at the first stage. The filaments which were melted under high temperatures are placed on a conveyor belt and then the nonwoven surfaces harden. In this way, the adhesion of the fibres to each other is obtained automatically.

Raw Material And Its Characteristics

The polymer products used in the production of geotextiles, can be given according to their consumption quantities as follows:

-Polypropylene (PP)	(~ 65%)	-Polyamide (PA)	(~2%)
-Polyester (PES)	(~ 32%)	-Polyethylene (PE)	(~1%)

As seen above, the mostly used polymers in the geotextiles production are PES and PE.

Comparison of The Fibre Characteristics

Characteristics	PES	PP
Specific gravity	1.38	0.91
Elongation	15-40	<350
Flexibility	Good	good
Moisture absorption rate %	0.4	0.05
Resistance against UV	Excellent	bad
Resistance against alkalis	Good	excellent
Resistance against acids	Good	excellent
Solvents in which they are soluble	Cresol, Phenol	-
Electrical conductivity	Good	good
Effects of the harmful insects like moth, and of molds and fungus	None	none

The geotextiles made of polyester are used in water structures more than polypropylene because the specific gravity of polyester is higher than of polypropylene.
PES based geotextiles have to face hydrolysis as a result of being used on or under the concrete structures and at the same time, because they are in a moist alkali medium. PES polymers are affected negatively if they are in contact with alkalis like $Ca(OH)2$ in the moist media. And when we assume that $Ca(OH)2$ is a substance existing in the structure of concrete, it has to be taken into account that the PES based geotextiles may not be used in applications where they can have direct contact to the concrete.
The geotextiles made of polypropylene, must be protected against UV rays if they shall be exposed to direct sunshine. This protection can be obtained by adding a UV protector still in the production stage of the PP polymers.

Functions of The Geotextiles

The geotextiles have mainly two functions:
Mechanical functions: -Separation: to hinder that the
Beneficial material is mixed
Into the weak soil

-Reinforcement: uniform distribution of all loads coming On itself, onto the whole area
-Protection: protection of the materials Which need to be protected Against outside effects

Hydraulic functions:
-Drainage: to allow the movement of The water on its level
-Filtration: to allow the water to flow Through and to detain the Particles at the same time

Features The Geotextiles Must Have

Mechanical features:
-tensile strength and break lengthening
-perforation strength
-tear resistance
-explosion strength
-visible opening dimension

Hydraulic features:
-permeability parallel to the plain
-permeability perpendicular to the plain

To be considered during the choise and use of Geotextiles

The followings have to be considered during the choise and use of geotextiles:
-First of all it has to be decided which type of geotextile with which grammage has to be chosen.
-UV protected geotextiles must be used during applications if they are exposed to the direct sun shine
-The overlap parts have to be taken into account during spreading the geotextile (10 cm at least).
-The geotextiles to be spread onto concrete, must be of polypropylene base.
-The chosen geotextile must meet the mechanical and hydraulic features which are needed by the detail where it has to be used (tensile strength, break lengthening, perforation strength and tear resistance as well as thickness etc.).

-Geotextile must be resistant against acids, alkalis, bacteria and micro-organisms which can exist in the medium where it has to be used.

Application Areas of Geotextile

Use of geotextiles in the construction sector goes on with a increasing acceleration in the last years. The main application areas are:
-Roads, highways, bridges and viaducts
-lakes, lake lets, watercourses,
-tunnels, underground installations, art structures, subways
-railways,
-sports grounds (golf links, tennis courts, carpet football area)
-coast protection
-depots (waste collection areas)
-airports
-agricultural fields, garden platforms,
-Isolation

Use of geotextiles on roads and highways:
It is necessary to avoid the mixing of the granules of the natural ground with the granular road upper layer to be spread on the natural ground during a road application to be made on a ground of lower low capacity. Otherwise, the fine natural ground granules mix into the granular layer and this lead to decrease of the permeability of this layer and porosities which cause then in various points collapses. To avoid such an event, a suitable geotextile is laid out between the two layers and the mixing of two layers is hindered while it is saved on aggregate which the way needs during its all life and has to be added, besides, the service life of the roads is increased.

Use of geotextiles on sports grounds:
Geotextiles carry out the separation and drainage functions on the sports grounds. They are laid down between the granular layer placed on the ground soil and the ground where the sports activities are carried out, the geotextile prolongs the drainage life, avoiding the penetration and blockage of the residues which might be transferred from the upper structure.

Use of geotextiles in garden platforms:
The geotextiles in garden platform details fulfil the separation and filtration functions. It is placed between the pebble layer that works for drainage, and the

vegetable earth, as a result thereof it helps to increase the drainage life, avoiding that the pebble layer fills the porosities. At the same time, it serves as filter, pushing the water within the body of the earth layer to the drainage layer.

Use of geotextiles in tunnels:
The functions of geotextiles in a tunnel application are separation, protection and drainage.
The direct contact of the geomembranes used for water impermeability at the construction stage of tunnels, with the concrete must be avoided. Therefore, the membranes are taken between two geotextile layers (sandwitching) and protected. (In tunnels, only PP based geotextiles have to be used). Furthermore, the geotextiles transmit the excess water quantities which could harmful to the tunnel, to the drainage points very fast because they are high impermeable along their whole length.

Use of geotextiles for isolation purposes:
Although the geotextiles alone have not the function of a isolation material, they are an indispensable part of the isolation details in the structures. They are placed between various isolation materials (water insulation membranes, heat insulation sheets etc.) and complementary materials (pebble and sand layers, mortar layers etc.) used in details, and avoid they mix together and are affected from the outside conditions. We can see all of the separation, protection, drainage and filtration functions of geotextiles, in the isolation applications.

Use of geotextiles on solid waste collection areas:
The first priority to be considered during generation of solid waste storage areas is to avoid the mixing of the waste water leakages from the collected wastes into the natural medium. And the only method therefore is to coat the whole natural ground of the waste storage area with impermeable materials (HDPE membranes). These covers with a thickness of only 2 mm which can be easily scratched and damaged, have no defence against the effects of the 25 cm thick filtration layer (pebble layer) to be laid down onto whole area and heavy waste layers with a height of hundreds of meters. Just at this point, the geotextiles are taken into consideration and laid down onto the whole membrane layer so that they have the protection function against the heavy loads and sharp and punching materials.

Conclusion

The contributions of the geotextiles to the successful civil engineering applications have become more distinguished in the last years. Sometimes, this was in form of a decrease in complementary periods which is too important in the construction sector, and sometimes, it was noticeable by its negative effect on the costs.
When the acknowledge and experiences of the engineers and users who include the geotextiles in their projects, increase, the reliance upon geotextiles will also increase and their use will be spreaded in time.

PROPERTIES AND CLASSIFICATION OF MEDICAL TEXTILES

N.Onar[1], M. Sarıısık[2]
[1]Pamukkale University, Faculty of Engineering, Textile Eng.Dep. , Denizli
[2]Dokuz Eylul Uni, Faculty of Engineering, Textile Eng.Dep, İzmir

ABSTRACT

Textile materials for medical are suitable for usage of all surgery field with together other non-textile materials. Medical textiles can be mainly classified as external medical applications and internal medical applications. Common raw materials for medical textiles are polyester, polyamide, polytetrafluoroethylene, polypropylene, carbon, glass fibers, cotton, viscose, silk, collagen, alginate, polycaprolactan, elastomeric fibers, polyurethane as natural and synthetic materials or absorbable and nonabsorbable. In the most case, medical textiles should be biocompatible, flexible, comfortable, softness, pliable, good fit; good tear strength, burst strength, abrasion resistant, tenacity; not toxic, allergenic and carcinogenic; should withstand sterilization by all known methods, i.e. by steam, radiation or gas etc.,pass flammability tests, should not allow skin irritation and reddening,; should not inhibit to movement, should have optimal costs. Moreover they should be able to a barrier to moisture and bacteria, not allow bacteria to penetrate, be water- and moisture- repellent or impermeable and to have air- and water vapour permeability (breathability), be able to prevent cross-infection in operating theatre, not be able to give rise to sweat or wetness from patient's skin

The aims of this work are generally to clarify the textiles which are used in all surgical applications and to summary requirements of medical textiles whilst based on compiling literature.

Key Words : Medical textiles, implantable, breatheability, water-repellent, barrier, absorbable, protection against infection.

INTRODUCTION

Textile materials for medical are suitable for usage of all surgery field with together other non-textile materials. Some properties of medical textiles have got strength and flexibility, wide products variety, very functional characteristics, biocompability with tissue, biodegradability, incorporation with another materials.[1]

The fastest improvements on medical textiles presented after invention of synthetic fibers. Then the rate of improvement had increased by finding nonwoven products on 1960's and proving reducing %56 the risk of cross-infection by using disposable products on 1985 year.

Protection of healtcare professionals against cross-infection from patients is very important based on functionally of medical textiles. Since viruses such as AIDS, hepatite may cross the staff from patient by contamination of blood and other infectious fluids whereas supplying on appropriate conditions. Furthermore their protective cloths must protect patients on the risk group against direct contact with patogenic microorganisms. It is generally required that medical textiles should be a barrier to moisture and bacteria, sterilizable with known methods, able to withstand prolonged handling and lengthy procedures, a non-slip surface of them, tough and waterproof, flexible, draping smoothly on application, readily conforming to patient's shape, good tear strength, linter-free, anti-static, economical when compared with equivalent items. [1, 4,7, 8, 9, 10]

The Classification of Medical Textiles

A) External Applications

1. Non-Implantable Textiles (Wound care, bandages, gauzes,plasters, lint, wadding, fiber optic elements)
2. Extra-corporeal devices (artificial liver, artificial kidney, mechanical lung)
3. Healthcare and hygiene textile materials (surgical cloths, surgical drapes, surgical gowns, surgical masks and caps, surgical hoisery, beddings, incontinence diaper/sheet, cloths/wipes, knees and elbows caps)

B) Internal Applications

1. Implantable Textiles (sutures, soft-tissue implants, orthopaedic implants, cardiovascular implants)[1,8]

Medical textiles can be product through weave, knitting and nonwoven processes. Recently, nonwoven textile surface is widely used in medical applications. because these products have got easy/suitable using, suitable prices, barrier properties, increasing effectiveness. Almost all of the surgical cover, drapes, towels, table cloths, masks, caps, shoe covers are mode nonwovens in United States. Nonwoven masks have got highly bacterial filtration, worn comfort, low cost and suitableness. Caps and shoe covers be made of nonwoven also supply suitableness and low cost advantage. Surgical packages and surgical covers are widely made spunlaced pulp/polyester, spunbond/meltblown/spunbond (SMS) polypropylene composites and wetlaid products. Low weight spunbond polypropylene, meltblown, carded rayon and polyester fabrics are used for masks and caps. Surgical package and cover made of nonwoven may be achieved barrier properties with combined chemical processes and/or film or membrane. [1, 5, 8, 13]

1. EXTERNAL APPLICATIONS

1.1 Non-implantable Products

The materials present the external of human body. They work on a situation with or without contact skin.Table shows properties and functions of non-implantable products.

Table 1.Properties and functions of non-implantable products[1, 8]

Product application	Fiber Type	Manufacture system	Functions
Wound care -Wound contact layer -Absorbent pad -Base material	Silk, PA, CV, PE Co, CV CV, Plastic Film	Knit, woven, nonwoven Nonwoven Nonwoven, woven	Protection against infection whereas absorption of blood and other fluids, healing and application of medication
Bandages	Co, CV, PA, Elastomeric Yarn	Knit, woven, Nonwoven	Keeping dressing over the wound
Plasters	CV, Plastic Film, Co, PP, PES, glass fiber	Knit, woven, Nonwoven	Application of medication, preventing move, merging sides of wound
Gauzes	Co, CV	Woven, nonwoven	Absorbing exudation or fluids
Wadding	CV, Cotton linters, Wood Pulp	Nonwoven	Whereas clogging any cavity
Lint	Co	Woven	In the treatment at mild burns
Fiber optic element			For improve viewpoint on operation rooms and carry laser ray

1.1.1 Wound Care

Wound care is composite material consisting of wound contact layer, absorbent pad and base material. Absorbent pad absobs blood or fluids and provides a cushioning effect to protecting the wound. Wound contact layer should prevent adherence of dressing to the wound. The base material provide application the dressing on wound and is coated with on acrylic adhesive to hold the dressing in place.

The colagen, alginat and chitin fibers are proven to be effecttive in healing of wounds. The interaction between the alginate fibers and exudating liquids creates a sodium calcium alginate gel which is hydrophilic, permeable to oxygen, impermeable to bacteria and helps with the formation of new tissue. [1, 5, 8]

1.1.2 Bandages

Bandages can be woven, knitted, nonwoven and elastic or non-elastic. The most common application for bandages is to hold dressings in place over wounds. Such bandages include light weight knitted or simple open-weave fabrics made from cotton or viscose which are cut into strips and then scoured, bleached and sterilised. Bandages consist of elastic bandages, compression bandages and orthopaedic cushion bandages. Elastic crepe bandages which are used for sprained wrist and ankle support, are woven from cotton crepe yarns. Compression bandages are used for the treatment and prevention of deep-vein thrombosis, leg ulceration and varicose veins and are designed to exert a required amount of compression on the leg when applied at a constant tension. Orthopaedic cushion bandages are used under plaster casts and compression bandages to provide padding and prevent discomfort. Nonwoven orthopeadic cushion bandages may be produced from polyurethane foams, polyester fibers or polypropylene fibers and contain blends with natural or other synthetic fibers. [1, 2, 8]

1.1.3 Gauze, Lint, Wadding

Gauze is an open weave, absorbent fabric. Paraffin-coated gauze is used the treatment at burns and scalds Lint is a plain woven cotton fabric that is frequently used in treatment of mild burns. Wadding is a highly absorbent material which is covered with a nonwoven fabric to prevent wound adhesion or fiber loss. Fiber optic elements provide focused ray for improving viewpoint on operation theatre. Moreover glass fiber is used for providing conduction on view area of surgeon and controlling blooding on stomach and intestine system.

1.2 Ekstra-corporeal Devices

Extra-corporeal devices and these functions illustrate on Table 2.

Table 2. Ekstra-corporeal Devices [1,8]

Device	Fiber Type	Application system	Functions
Artificial kidney	Hollow viscose, hollow polyester fiber, PAN, Polymethylmetacrilate, chitin	Hemodialysis (HD) Hemodifiltration (HF) Hemodifiltration (HP)(HDF)	Remove waste products from patient's blood
Artificial liver	Hollow viscose, Carbon fiber, Polyethyerurethane	Plasmapheresis (PP) hemoperfusion (HP)	Separate and dispose patient's plasma and supply fresh plasma
Mechanical lung	Hollow polypropylene fiber, hollow silicone, hollow silicone membrane, polysulphone	Hemoperfusion (HP)	Remove carbondioxide from patient's blood and supply fresh oxygen

1.3 Healthcare and Hygiene Textiles

Healthcare and hygienic products are an important sector in the field of medicine and surgery. The range of products avaliable is vast, but typically they are used either in the operation theatre or on the hospital ward for the hygienic, care and safety of staff and patients.

1.3.1 Surgical Cloth (Dress, cap, mask ,hoisery)

Surgical cloth provide act as a barrier as preventing carrying patogenic misroorganisms (hepatit, AIDS) to surgery personel from patients or cross-infection patients from personels by airborne or fluid stream. Gowns makes rather different demands on a nonwoven and this affects the choice. The caps must be comfortable to wear i.e. the material must ve softness, pliable, air-permeable, virtually lint-free and also sterilizable, even though headgear is not normally sterilized. Nonwoven disposable surgical caps are made of cellulosic fibers with the parallel-laid or spunlaid process. Hydroentanglement is gaining popularity in producing disposable products and garments for operation room. More effective masks giving 85% or even 99% protection are required to prevent the spread of infection. This degree of effectiveness is attained with a very fine filter of extra-fine glass fibre or more recently extra-fine textile fiber covered on both sides with conventional nonwoven bonded fabric. Polypropylene, polystrene, polycarbonate and other polymer fibers are suitable substitutes for extra-fine glass fiber. Performance properties for surgical face masks are high bacterial filtration capacity, high air permeability, lightweight and non-allergenic.

Composite materials are used consisting of 3 layers with a very fine filter layer in the middle. The inner and outer covering is usually made of acrylic bonded paralel-laid or wet-laid nonwovens. The surface filter layer is composed of microfibers of glass, polyester, polypropylene or polycarbonate.

1.3.2 Surgical Drapes

Surgical drapes ensure a sterile working area during operation and provide sterile cover cloths hospital personels. The general requirements are impermeability to water and bacteria, absorption of secretion, air and water vapour permeability (beathability) and mechanical stability. The choice of material generally is spunlaced nonwovens which are used as backing material on one or both sides of a polyethylene film. Whereas superabsorber nonwoven fabric absorbs body sweat and secretions, film act a barrier for bacterias.

The materials are applicated hydrofobic finishing and antibacterial finishing for proper bacteria barrier. Back to back laminated loop-raised warp knitted polyester

Table 3. Healthcare and Hygiene Textiles

Products application	**Fiber Type**	**Manufacturing System**	**Functions**
Surgical cloths - Dress - Cap - Mask - Surgical hoisery	 Co, PES, PP, Carbon fiber CV CV, PES, glass fiber PES, PA, Co, Elastomeric yarns	 Woven, nonwoven Nonwoven Nonwoven Knit	Preventing cross-infection patient from personel and protect to carrying patogenic microorganisms personel from patients, to prevent spreading body particles,act a barries to dusts Treatment for disturbances concerning veins. To support, compression and protect
Surgical Drapes - Curtain - Drapes	 PES, PE PES, PE	 Nonwoven, woven Nonwoven, woven	To cover surronding area of patient, to prevent cross-infection and carrying fluids
Bedding - Quilt - Blanket - Sheet - Mattress - Pillowcase	 PES,PE Co, PES Co Co Co	 Nonwoven, woven Woven, knit Nonwoven, woven,knit Woven Woven	 To prevent infections and carrying fluids
Incontinence pads (diaper, sheet) - Coverstock - Absorbent/core layer - Backsheet	 PES, PP Superabsorber, viscose, wood fluff PE	 Nonwoven Nonwoven Nonwoven	 Absorbing body fluids, providing hygiene and safe
Wipes	CV	Nonwoven	To clean wound and skin, to treat rashes and burns
Knee and elbow caps	Elastomeric yarns		Protecting and providing support and compression during physical and active sports

fabrics, containing a microporous PTFE film in the middle, provide permeability and comfort as well as resistance to microbiological contaminants.

1.3.3 Bedding (Sheets, pillowcase, quilt, blanket, cushion)

Woollen blankets was used twenty five years ago in hospitals. But infection can be spread by their piles carrying bacteria, and they are convenient for vapor sterilization and they can not be often washed due to their felting shrinkage risk. Therefore these replaced cotton weave blanket which are made from soft-spun two-fold yarns, whereas provide reducing infection risk. These posses the desirable thermal qualities, are durable and can be easily washed and sterilised.

Sheets for hospital generally is cotton with polyester, polyethylene used for sheets in USA hospitals. In recent years it would be desirable for disposable nonwovens to be used as bed linen in hospitals to break the chain in the spreading of infection [1,5,8].

1.3.4 Incontinence Diapers, Baby Napkins and Feminine Hygienic Products

It includes disposable baby diapers, training pants, feminine hygiene products (sanitary napkins and tampons), and adult incontinence products which are collectively called absorbent products. Diapers are divided in to three categories as <u>baby diapers, training pants and pant diapers</u>. Functions of <u>baby diapers</u> are to absorb urine during the miction, to retain urine inside the absorbent core, to isolate wetness from the baby's skin, to isolate urine and faeces from the baby's environment, to prevent infection to the baby's skin. Functions are desired with the one or all of properties such as maximum comfort, good fit, good practical usefulness, no noise, no diaper rash. <u>Training pants</u> were originally made to help or to train the babies or small infants to become clean. The important difference between <u>pant diapers</u> and training pants is that the absorption capacity of the pant diaper is equivalent or better than a corresponding child size diaper.

The essential parts or components of the diaper are <u>top sheet/skin touch layer(coverstock), absorbent core layer, backsheet</u>. The diaper <u>coverstock</u> is a critical element in the rapid acquisition of liquid, and is the main part of the diaper in contact with a baby's skin. The relatively simple function of passage of liquid to the interior of the structure needs to be combined with adequate strength, softness, good surface abrasion, and fast 'strikethrough', coupled with minimal wetback. Topsheet is generally spunbond or thermalbond fabric made of hydrophobic polypropylene fibers. Increasingly, spunbond is becoming the fabric of choice because it is cheaper to produce, and modern machinery ensures lightweight and high uniformity. Treatment with surfactants can improve the performance of the topsheet, while some cheaper diapers use apertured hydrophobic film treated with a surfactant. Modern diaper <u>absorbent cores</u> actually consist of two layers - the surge layer, which attracts and evenly distributes fluid, and the core which absorbs and locks up the fluid. There are increasing moves to combine these two layers into one composite, airlaid- and superabsorbent-based structure to simplify diaper construction. The surge, or wicking, layer is made of hydrophilic fibers, generally airlaid wood pulp dryform fabrics made from a number of fibers including polyester and rayon, and thermally or through-air bonded. Its job is to draw fluid through the topsheet then absorb and distribute it almost instantaneously by capillary action. The fibers hold onto the fluid until the absorbent material in the central core absorbs it. The absorbent core in the center of the diaper generally consists of superabsorbent polymer (SAP) and fluff pulp in proportions that vary depending on the diaper line. The inclusion of more SAP allows thinner diapers to be made because it absorbs up to 10 times more liquid gram for gram than bulkier fluff pulp. However, fluff pulp is still an essential element due to its capillary action that distributes fluid to the SAP throughout the core. It also helps prevent gel blocking of the SAP which occurs when absorption of water on to a SAP particle slows after initial rapid swelling. The outer surface of the diaper as backsheet is vital in preventing fluid from soaking through from the core, and therefore needs to be impervious to liquid.

Feminine hygiene is the most well developed absorbent product market in the world, with higher global market penetration than both diapers and adult incontinence products.

Coverstock used in feminine hygiene products is predominantly thermally bonded, compared to diaper coverstock which is increasingly manufactured using spunbond processes. The remainder of the nonwovens used in femcare products is a combination of airlaid, spunlace, through-air bond and other fabric types that are used in the absorbent core structure of the products. In addition to the continuing use of thermally bonded fabrics in coverstock, laminates of nonwovens and apertured films alone are being increasingly used as topsheet due to their superior wicking and rewet performance.

As with other absorbent products, an increasing amount of elastomers and elastomeric SMS fabrics are being used to improve the fit and comfort of sanitary napkins, particularly as product differentiation has increased during the 1990s with the introduction of curved or contoured pads, and greater variations on wings or tabs.

Functions of the napkins are to absorb and retain menstrual fluid, to isolate menstrual fluids from the body. Important / desired properties are no leakage, no unaesthetic appearance or color, no odor , no noise, stay in place, comfortable to wear (thin body shape).

Adult incontinence products are used to address the problems of the adults. They are subdivided according to the severity of the problem ,as is the suitability of products designed for dealing with it such as heavy incontinence, medium – low level incontinence. The primary requirements of products designed to deal with heavy incontinence are to absorb urine during the miction and subsequently distribute the urine throughout the absorption pad, to retain urine and faeces inside the product, to isolate wetness from the skin, to reduce odor. The products should achieve the above mentioned functions with due regard to maximizing comfort, simplicity. Primary requirements of products designed for medium – low level incontinence are to absorb urine during the miction and distribute the urine throughout the absorption, to retain urine effectively in the absorbent core, to isolate wetness from the skin, to reduce potential odor problems caused by urine degradation. The products should achieve the above mentioned functions with due regard to maximum wearer comfort, good product fit, good level of discreteness with the product, simplicity – ease to use and put on / take off, low noise level. [13, 3, 6]

1.3.5 Wipes

After wet napkins for airways passengers are found, trends to this type materials increased. The reason of the trend is protective package, easiness for storage and practicability of materials. Pads for removing make-up and fingernail, materials for aftershave and skincare increasingly become popular.

1.3.6 Knee and Elbow Caps

Knee and elbow caps for physical active sport, which are producted on circular knitting machine and contain elastomeric yarns, is used to give compression, support and protection.

2. INTERNAL APPLICATIONS

2.1 Implantable Products

Table 5 shows implantable products with their manufacturing systems and fiber type.

Table 5. Implantable products. [1,8]

Product application	Fiber type	Manufacturing system
Sutures		
- Biodegradable	Colagen,polylactide,polyglycolide	Monofilament , braided
- Non-biodegradable	PA, PES, PTFE	Monofilament , braided
Soft-tissue implants		
- Artificial tendon	PTFE, PES, PA, PE, silk	Woven, braided
- Artificial ligament	PES, Carbon fiber	Braided
- Artificial cartilage	LDPE	Nonwoven, fibre composite
- Artificial skin	Chitin	Nonwoven
- Eye contact lense/artificial cornea	Polymetylmethacrylate, silicone, colagen	
Orthopeadic implants		
- Artificial joints/bones	Silicone, polyacetal, PE,	Fiber composite
Cardiovascular implants		
- Vascular grafts		Knit, woven
- Heart valves	PES, PTFE	Woven, knit
	PES	

2.1.1 Sutures

Sutures are mono- or multi- filament threads that are used to close wounds, join tissue and tie off bleeding vessels. In the thirties, silk and linen were used as sutures until the development of nylon. Then BASF developed a " pseudo-monofilament", which was a combination monofilament and multifilament material. In the wound-closure market, companies continue to developed advanced sutures made from bioabsorbable polymers as polyglycolic and polylactic acid, synthetic absorbable suture materials. Suture materials can be classified as absorbable and non-absorbable sutures. Absorbable fibers such as cotton, viscose, polyamide, polyurethane collagen (catgut) and alginate, polyglycolic acid, polyglycolic acid- polylactic acid copolymer, polydioxanone and polyglycolic acid-polycarbonate copolymer are chemically decomposed by the body after 2-3 months. Polyester, polypropylene, "expanded" polytetrafluoroethylene (ePTFE) and silk require more than 6 months for this process and are called "non-absorbable". Absorbable sutures are advantages in many internal applications as a second surgery for suture removal is not desired. The selection of suture is related to using application area. It can be wanted that short or long time absorbtion and long time stability, strength. However requirements of sutures generally can be stated that these should be sufficent tensile strength, flexibility, easily sterilisable, minimum tissue retention, absorbable before healing of wound, not hurt tissue, non-capillarity, non-sliding, knot security, and handling characteristics, biocompability with tissue, no allergic, no cancerogenic, effectiveness on cost. Furthermore these should be made of material that is suitability for using on any operation and protect its strength when infection, easily manufactured, provide easily seaming.[1, 3, 8, 11, 12, 14]

2.1.2 Soft Tissue Implants

The strength and flexibility characteristics of the textile materials make them particularly suitable for soft-tissue implants. A number of surgical applications utilise these characteristics the replacement of tendons, ligaments, and cartilages in both reconstructive and corrective surgery.

Important properties that affect cell attachment and tissue growth are chemical structure, electrical charge, hydrophilicity and hydrophobicity, roughness of surface, microheterogeneity and material flexibilty.

Soft tissue compatible biological polymers are collagen, silk protein, cellulose, chitin and chitosan. Collagen, which is a main component of soft tissue in the human organism, is a protein which forms connective tissue in vivo.

Soft tissue compatible artificial materials include silicone rubber, polyurethane, hydrogels and carbon fiber. Silicone rubber is a crosslinked polymer as poly(dimethyl siloxane). It has been used in artificial breasts, ears and noses. Hydrogels are insoluble water-containing materials. These are made by introduction of either crosslinks, hydrophobic groups, or crystalline domain into water-soluble polymers. High water content inhibits cell attachment and growth, but gains good oxygen permeability. Carbon fibers are used to repair joints in the arm, shoulder, knee and ankle. [1,8]

2.1.3 Orthopeadic Implants

Orthopeadic implants are those materials that are used for hard-tissue applications to replace bones and joints. Also fixation plates, which are implanted to stabilise fractured bones, are included in this category. Fiber-reinforcement composite materials may be designed with the required high structural strength and biocompability properties needed for these applications and are now replacing metal implants for artificial joints and bones.

Textile structural composites such as carbon composites are replacing metal implants for this purpose. A nonwoven fibrous mat made of graphite and PTFE is used around the implant to promote tissue growth. [1,8]

2.1.4 Cardiovascular Implants

Vascular grafts are used in surgery to replace damaged thick/arteries or veins. Commercially avaliable vascular grafts are produced from polyester fiber (e.g. Dacron) or PTFE fiber (e.g. Teflon) in either woven or knitted structures. Straight or branched grafts are possible by using weft- or warp- knitting technology.

Artificial heart valves which are caged ball valves with metal struts, are covered with polyester fiber fabrics in order to provide a means of suturing the valve to the surrounding tissue. [1,8]

CONCLUSION

Consequently we can say that medical textiles products include wide variety of their products and the variety and using of them continuously increase. Besides it is estimated that meeting adequencing requirements of specific performance properties of these products will tend in next future.

REFERENCES

1. Adanur, S.(1995), "Wellington Sears Hanbook of Industrial Textiles", Technomic Publishing, pp. 329-355
2. Anand, S.(July 2000), "Developments in technical fabrics-Part1", Knitting International, No: 1272, pp. 32-35
3. Cottenden, A.M., Dean, G.E., Brooks, R.J. (1997), "Predicting the leakage performance of small bodyworn disposable incontinence pads using laboratory tests", Med. Eng. Phys., Vol. 19, No. 6, pp. 556-571.
4. Kälberer, K. (July 2000), "Medical Textiles", Asian Textile Journal, p. 53-54
5. Lickfield, K.D. (August 2001), "Nonwovens in Medical Textiles", International Fiber Journal, pp. 42-48
6. Lünenschloss, J., Albrecht, W. (1985), "Poroperties and end-uses of nonwoven bonded fabrics", Nonwoven Bonded Fabrics, JohnWiley& Sons Press, pp.393-403
7. Malik, A.(January 2001), "Polymers and fibres in disposable medical products", Asian Textile Journal, pp. 36-40
8. Purdy, A.T. (1983) "Developments in Nonwoven Fabrics", Textile Progress, The Textile Institute, V.12, N.4, pp. 51-55
9. Rigby, A.J., Anand, S.C., Horrocks, A.R. (1997), "Textile Materials for Medical and Healthcare Applications", J.Text.Inst., 88, Part 3, pp. 4-31
10. Wollina, U. (1998), "Medicine and health care- new demands on textile quality?", Melliand International (3), pp210-211
11. Walker, I.V.(September 2001), "Nonwovens-The choice for the medical industry into the nexy millennium", Asian Textile Journal, pp. 122-125
12. www.devicelink.com/mpb/archive/98/01/001.html
13. www.devicelink.com/mpb/archive/98/03/002.html
14. www.eng.clemson.edu/~pichhap/projects/Products.doc
15. www.unik.com.tw/htm/a-1.htm

SEARCHING THE USAGE OF MEDICAL TEXTILES IN PERIPHERIC NERVE TISSUE DAMAGES AS REINFORCED GRAFTS

N.Yıldız
Pamukkale University Textile Engineering Department, Denizli

ABSTRACT

Textile materials in the medical field gradually have taken on more important roles. As more research has been completed, textiles have found their way into a variety of medical applications. In addition to protective medical apparel, textiles in fiber and fabric form are used for implants, blood filters and surgical dressings. Textile structures in implantation are identified by structure, material composition and behavior of fiber surface and degradation. A major concern with artificial implants is the reaction the body will have towards the implant. A biotextile in implantation must meet mechanical requirements and it must be biocompatible. In this study, the usage of medical textiles are searched in peripheric nerve tissue damages as reinforced grafts. Peripheric nerves are consist of nerve fibers coming from spinal cord to muscles. These nerves are far away from central system, so making repair on peripheric nerves is more possible. Polytetraflouroethylene (PTFE), silicone and collagen medical textile materials in reinforced graft forms are searched according to their biological, mechanical and chemical properties and they are compared in order to search the best reinforced graft of medical textiles which are thought to be used in peripheric nerve tissue damages.

AIM

Searching the usage of PTFE, silicone and collagen medical textile grafts in peripheric nerve tissue damages and trying to identify the suitable material.

1. INTRODUCTION

Peripheric nerves bridge between spinal cord and muscles. Being far away from central nervous system making repair on peripheric nerves are more possible compared to central nerves. Peripheric nerves require main properties as biological, mechanical and chemical properties. Using these properties the non-toxic, the ability to be sterilized, biodegradability, biocompatibility, inertness, strength, elasticity and durability of PTFE, silicone and collagen biomedical polymers and grafts are searched.

2. MATERIAL AND METHOD

PTFE , silicone and collagen grafts are searched. Polymer properties have an important role in the properties of the grafts. So also polymer properties are being searched. The Carbon backbone of PTFE is completely covered by the "electron cloud" of Flourine atoms. This covering results in the exceptionally high chemical and thermal resistance [1].

Monomer	Polymer
$nCF_2 = CF_2$	$-[CF_2 - CF_2]-$

Fig 1: PTFE Model [2]

This stable structure makes PTFE molecules neutral about electrical properties. PTFE has a lower coefficient of friction than that of ice [1]. Extremely low intermolecular forces are the reason why PTFE offers the lowest friction coefficient of all solid compounds. Sliding properties of PTFE are excellent. Resistant against light and weather. For this reason, PTFE offers unlimited suitability for outdoor applications, including extreme weather conditions, without any notable changes of its mechanical or electrical properties [3].

Table 1.Physical properties of PTFE compared to fluorine-containing thermoplastics [3]

Physical properties of PTFE compared to fluorine-containing thermoplastics

Material				**PTFE**	**FEP**	**PFA**	**PCTFE**	**PVDF**
Properties		**Testing methode**	**Unit**					
Density	23 °C	DIN 53479	g/cm^3	2,15-2,19	2,12-2,17	2,12-2,17	2,10-2,20	1,76-1,78
Tensile strength at break	23 °C	DIN 53455	N/mm^2	22-40	18-25	27-29	30-38	38-50
Percent. elong. at break	23 °C	DIN 53455	%	250-500	250-350	300	80-200	30-40
Modulus in tension	23 °C	DIN 53457	N/mm^2	400-800	350-700	650	1000-2000	800-1800
Melting temperature		ASTM 2116	°C	327	253-282	300-310	185-210	165-178
Coefficient of thermal exp. 10^{-5}		DIN 52328	K^{-1}	10-16	8-14	10-16	4-8	8-12
Thermal conductivity	23 °C	DIN 52612	$W/K \cdot m$	0,25	0,2	0,22	0,19	0,17
Water absorption		DIN 53495	%	<0,01	<0,01	<0,03	<0,01	<0,03

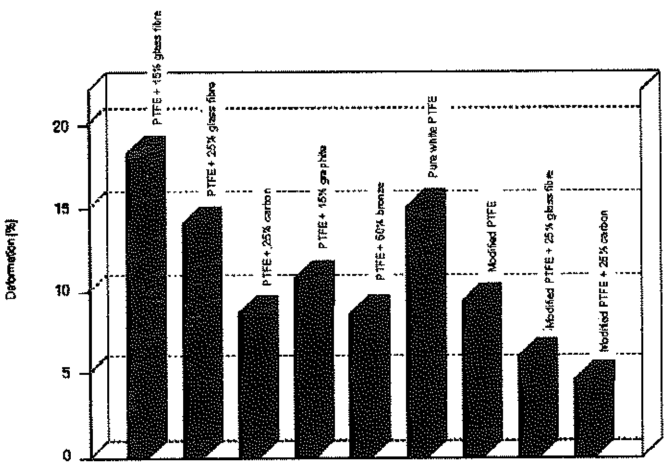


Fig 2. PTFE and PTFE Compounds Deformation Under Load ASTM D621 (15 N / mm^2, 100 h, 23 °C) [3]

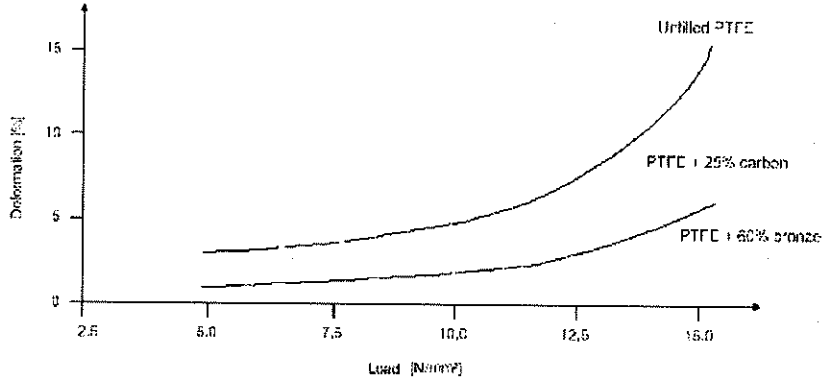


Fig 3. PTFE and PTFE Compounds Deformation Under Load
(Test Temperature: 23 °C and Test Duration: 100 h) [3]

PTFE is considered to be one of the most unreactive implantable polymers along with not absorbing water. However, it has several unfavorable physical properties such as low strength, abrasion resistance and flexural modulus. In addition, when fragmented, PTFE can cause tissue irritation. PTFE is often used in reconstructive surgery despite its low strength due to its inertness [4]. The streched or expanded PTFE tube has a microfibrous structure defined by the presence of nodes interconnected by fibrils[5].

Figure 4. Gore-Tex PTFE Biomaterial[6] Figure 5: Teflon Mesh Biomaterial[6]

The strength of PTFE fibres show difference according to be in monofilament and multifilament forms. Generally, wet and dry strengths are 0.5 g/denier, for

multifilaments are between 1.2-1.5 g/denier. It's density is 2.1. These filaments are non-combustible, non-flammable and melt as decomposing [7].
Silicones, long known to be biostable and biocompatible in most implants. Also frequently have the low hardness and low modulus that are useful in many device applications. Conventional silicone elastomers can have fairly high ultimate elongations, but only low-to-moderate tensile strengths. Consequently, as measured by the area under their stress-strain curves, the toughness of most biomedical silicone elastomers, is not particularly high [8].

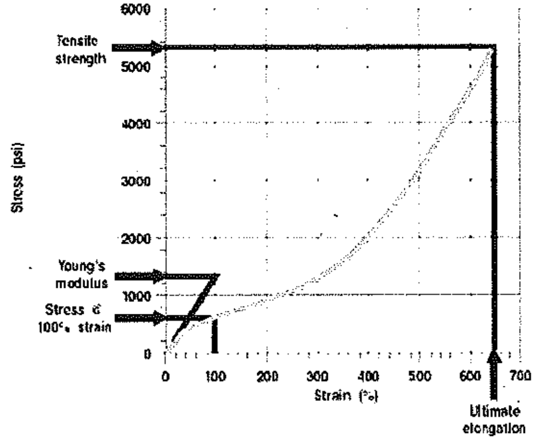


Fig 6. Stress-Strain Curve for Silicone [8]

In biomedical applications, silicone is produced by two different vulcanization processes; heat vulcanization and room temperature vulcanization. These methods produce materials with a wide range of physical properties. In general, silicone has favorable tissue compatibility and shows little deterioration. In addition, silicone has easy formability which is why it has been used extensively in soft tissue replacement in reconstructive.

Table 3. Silicone Biomaterials Properties [4]

Property	Heat Vulcanized Soft	Heat Vulcanized Hard	Room Temp. Vulcanized
Density (g/ml)	1.12	1.23	1.13
Tensile strength (MPa)	6	7	2.8
Elongation (%)	600	350	160

Collagen is a comprised of a triple helix formed by three protein chains wrapped around one another to create a fibril. Unextendable collagen fibrils have high tensile strength and are cross-linked together in the extracellular space. Within each collagen fibril, there exits a regular repeating arrangement that creates a striped pattern on the surface of the fibril. Collagen provides tensile strength and elasticity to matrices that support the cells in the body including tendons, cartilage and bone. Because of collagen has been identified as a mildly antigenic fibrous protein it has been considered suitable for use as a biomaterial. In addition, collagen a biological macromolecule, has been found to have low immunogenicity, absorbability, biodegradation rate and cell interaction [9]. Collagen fibers are as strong as silk and are being used majorly as sutures and also have a wide range usage of nerve grafts.

Fig 7. Natural Collagen Vascular Graft of Artegraft Company [10]

Collagen graft handles and feels like native vessel and has a minimal or no suture line bleeding and superior tensile strength permits lateral and longitudinal expansion without weakening the graft. 100% biological collagen materials are nonreactive and nonantigenic [10].

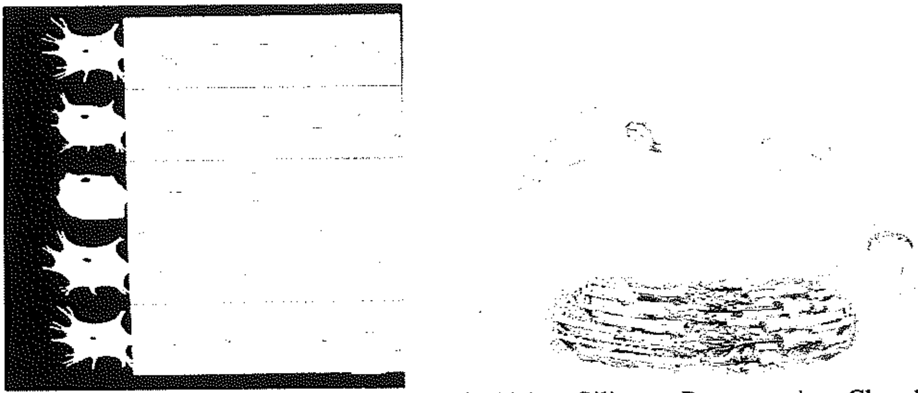


Figure 8. Nerve Regeneration and Repair Using Silicone Regeneration Chamber Model [11]

In bioartificial nerve grafts multiple longitudinal filaments act as guidelines for axonal growth inside silicone tubes. Using this type of bioartificial nerve grafts extended gaps in the continuity of rat sciatic nerves have been successfully bridged [11].

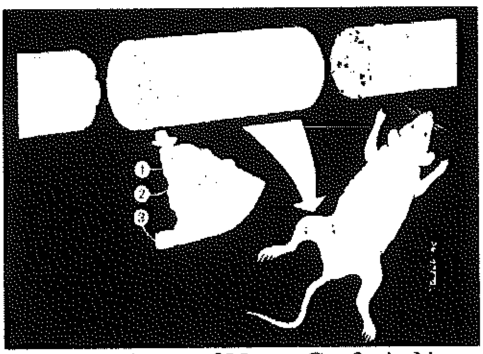


Figure 9. Usage of Nerve Grafts in Nerve Regeneration [11]

In peripheric nerve tissue damages, firstly damaged nerves are extracted and nerve grafts are replaced. As the nerve cells or tissues are thought to be 0.83 mm. length regeneration per day, in one month there will be a 25mm. regeneration and the nerve regeneration is completed. And than the used grafts are extracted. According to the example, a one month strength of the graft can be enough. Besides mechanical, chemical and biological properties of peripheric nerve grafts also the continuity of knowledge flow is important [11].

3. RESULTS AND DISCUSSION

The thermal resistance of PTFE has a range of minus 260° to plus 300°. No other standard industrial compound can achieve this temperature range. These values provide PTFE grafts to be sterilized the best. Being physiologically neutral, PTFE grafts has frequently been implanted into living tissues without any incompatibility having been noted. Another advantage of PTFE grafts are being inert compared with the other medical textile grafts. They are used in neurological surgery to minimize tissue attachment, provide a plane of dissection at reoperation , and serve as a physical barrier between tissues. But these synthetic graft materials often cause a severe inflammatory reaction. PTFE grafts have low friction coefficient. This property causes failure while tissues attaching to the grafts and an insufficient growth occurs. Having high rigidity values is another disadvantage. When compared as biologically silicone grafts are the most inert and chemically stable polymers. Silicone and PTFE grafts have so low reactivity that they cannot attach any surface. Collagen grafts have low bursting strengths. Although having this disadvantage, their advantages are so much. Collagen is a main structural component of tissues in the human body and is often used in the medical and biomaterial industry. Since collagen acts like 'glue' holding connective tissue together, there are many future developments for collagen as a synthetic biomaterial. It is biodegradable and has good mechanical properties. Being more closely mimics the body's natural function and other properties makes collagen grafts the best nerve grafts among other graft usages.

REFERENCES

1) Student Projects Page, Arizona University, 1998
http://aml.arizona.edu/classes/mse222/1998/teflon/properties.htm
2), Ralph H. Petrucci, California State University, San Bernardio, William S. Harwood, University of Maryland, College Park, 'General Chemistry Principles and Modern Applications', 1993
3)Elringklinger Company, Kunststofftechnik
http://www.elring-kunstoff.de/pages/e_werkst_elring_ptfe.htm
4)Kroschwitz, Park, 'Polymeric Biomaterial Applications', North Carolina State University,1984,1989
http://bae00du.bae.ncsu.edu/bae/research/blanchard/www/465/textbook/otherprojects/bioimplant/project/poly.html
5)Peter J. Schmitt, Textile Engineer, Product Manager
http://texdev.com/cv.htm

6)Parvis K. Amid, Alex G. Shulman, Irwing L. Lichtenstein, Lichtenstein Hernia Institute, Los Angeles, Reprinted From Postgraduate General Surgery, 1992
http://www.perfixplug.com/newart5.htm

7)Prof. Dr.Mustafa Harmancıoğlu, "Rejenere ve Sentetik Lifler", 1981

8)Robert S. Ward, President of the Polymer Technology Group Inc. (Berkeley, CA), 2000
http://www.devicelink.com/mddi/archieve/00/04/011.htm

9) Dr. Michael Yu, Michael A, Angela Au, James Bankard, Paul Roberts, Bobeck Nazer, Sid Tania, Judy Wang, 'Collagen Copolymers and Their Medical Applications', John Hopkins University 2002
http://www.jhu.edu/~matsci/teaching/510.420/Presentation%2042202.doc

10)Artegraft Company, Surgical Versatility
http://www.artegraft.com/surgvers.htm

11) Prof. Dr. L. M. Bjursten. , , Bioimplant Research, M. Kanje, Animal Physiology, N. Danielsen, Cell Biology and Neuroscience, 'Experimental Research', 2000
http://www.hand.mas.lu.se/Exper.html

GEOSYNTHETICS AND COMMON USAGE IN ENGINEERING STRUCTURES

H. R. Yılmaz, R.A. P. Aklık, R.A. T. Eskişar
Ege University, Engineering Faculty,Civil Engineering Department, İzmir

ABSTRACT

In civil engineering applications, geotextile, geogrid, geonet, geomembrane, geocomposite, geopipe, and geosynthetic clay liners which are named as geosynthetics are used to improve soil behaviour in soil which all have widespread usage areas in engineering purposes.

1. INTRODUCTION AND AIM

Geosynthetics are polimeric materials which are used in various places and aims, and also they take place in various application areas in civil engineering. Geosynthetics, which are developed and produced by textile engineers, are giving an opportunity to qualified projects for civil engineering applications because of their economic and high resistance. Also in applications, geosynthetics are the first choice in soil improvement methods for strengthening soft soils. The purpose of this study is to explain the role of textile products in civil engineering applications and their importance. Widespread usage areas are explained with pictures and short statements.

2. SHORT HISTORY ABOUT GEOSYNTHETICS

In civil engineering applications, the oldest constructions which geosynthetic fabrics have been used, are the civilizations in China And Rome Empire. There are many examples which belongs to 4500 years ago. These examples include usage of natural felt, fibres and leather for the seperation of soil and reinforcement. The main differences between of today's usage and the olders in using the geotextiles are as follows:

1. The properties of the materials which are used today are better known.
2. Because of this, the approaches which are tended to project are numerical and analytical.

As looking through the modern civil engineering applications, the first example in 1930's is Indian Hemp fabric used for the support beneath the Aberdeen city roads.

3. DEFINITION OF GEOSYNTHETICS AND THEIR SPECIES

Geosynthetic is defined as "a planar product manufactured from polymeric material used with soil, rock, earth or other geotechnical engineering related materials as an integral part of a man-made project, structure or system."

At the beginning of 1990's, from the aspect of the consumption, 84 % geotextiles, 10 % geomembranes and 3 % geonets and other types have been used in USA. Because of this reason, sometimes the term "geotextile" is used instead of the term "geosynthetic". There are various variety of geosynthetics and these main groups are:

1. Geotextile
2. Geogrid
3. Geonet
4. Geomembrane
5. Geosynthetic clay liner
6. Geopipe
7. Geocomposite

Geotextile: A permeable geosynthetic comprised solely of textiles in a human-made projects, as a structure of system.

Geomembrane: With very low permeability synthetic membrane liners or barriers used with any geotecnical engineering related material so as to control fluid migration in a human-made project, structure or system.

Geogrid: A geosynthetic used for reinforcement which is formed by a regular network of tensile elements with apertures of sufficient size to allow strike-through of surrounding soil, rock or other geotecnical materials.

Geonet: A geosynthetic consisting of integrally connected parallel sets of ribs over lying similar sets at various angles for planar drainage of liquids or gases.

Geosynthetic clay liner: A favctory manufactured, hydraulic barrier typically consisting of bentonite clay or other very low permeability material, supported by geotextiles and/or geomembranes which are held together by needling, stitching or chemical adhesives.

Geopipe: The traditional materials used for underground pipeline transmission of water, gas, oil and various other liquids have been steel, cast iron, concrete and clay.

Geocomposite: Geocomposites consist of various combinations of geotextiles, geogrids, geonets, geomembranes and/or other materials.

4. THE FUNCTIONS OF GEOSYNTHETICS

Can be explained in six headlines:

1. Separation
2. Filtration
3. Drainage
4. Reinforcement
5. Protection
6. Sealing-Moisture barrier

Separation is a function of preventing two different soils from mixing. Reinforcement is a function of obtaining tension resistance in soil. Filtration is permitting water flow perpendicular to geotextile plane. Drainage is satisfying the procedure of water flow on the geotextile plane. Protection is the procedure of preventing harmful external factors. Sealing is the procedure of repaving asphalt layers with absorbing bitum in the construction of asphalt layers.

Functions of the geosynthetic species are shown below in the table denoting as "P" primary, "S" second and "NA" not applicable.

Table 1. Appropriate functions for the species of geosynthetics [3].

TYPE	APPROPRIATE FUNCTIONS				
	separation	**reinforcement**	**filtration**	**drainage**	**sealing**
geotextile	P/S	P/S	P/S	P/S	NA
geogrid	S	P	NA	NA	NA
geonet	S	S	NA	P	NA
geomembrane	S	S	NA	NA	P
geocomposite	P/S	P/S	P/S	P/S	P/S

The most widespread geosynthetic species is geotextiles. The raw materials (polimers) of the geotextiles are:

1. Poliolefin
1.1. Polipropilen
1.2. Polietilen
2. Poliester (Terilen)
3. Poliamid(Nylon)
4. Polivinil clorur (PVC)

The properties of geotextiles related to raw materials are shown in the table below as 1-2-3.

Table 2.The properties of geotextiles related to raw materials [2].

<table>
<tr><th colspan="2">Properties</th><th>Poliester</th><th>Poliamid</th><th>Polipropilen</th><th>Polietilen</th></tr>
<tr><td colspan="2">Resistance</td><td>3</td><td>2</td><td>1</td><td>1</td></tr>
<tr><td colspan="2">Modulus of elasticity</td><td>3</td><td>2</td><td>1</td><td>1</td></tr>
<tr><td colspan="2">Elongation at rupture</td><td>2</td><td>2</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Creep</td><td>1</td><td>2</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Unit weigth</td><td>3</td><td>2</td><td>1</td><td>1</td></tr>
<tr><td colspan="2">Cost</td><td>3</td><td>2</td><td>1</td><td>1</td></tr>
<tr><td colspan="6">Resistance to circumstances</td></tr>
<tr><td rowspan="2">U.V. light.</td><td>Stabilised</td><td>3</td><td>2</td><td>3</td><td>3</td></tr>
<tr><td>Not stabilised</td><td>3</td><td>2</td><td>2</td><td>1</td></tr>
<tr><td colspan="2">Alkali</td><td>1</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Micro Organisms etc.</td><td>2</td><td>2</td><td>2</td><td>3</td></tr>
<tr><td colspan="2">Fuel Oil</td><td>2</td><td>2</td><td>1</td><td>1</td></tr>
<tr><td colspan="2">Detergent</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
</table>

3: high, 2: medium, 1: low

5. EXAMPLES ABOUT THE USAGE OF GEOSYNTHETICS

5.1 Geotextiles

5.1.1 Separation Function of Geotextiles

Between subgrade and stone base in paved or unpaved roads and airfields, between subgrade and ballast in railroads, between foundation soils and rigid or flexible retaining walls, beneath parking lots, beneath sport and athletic fields, between old and new asphalt layers.

5.1.2 Reinforcement Function of Geotextiles

Over soft soils for railroads, airfields, unpaved roads and landfills, for lateral containment of railroad ballast, to reinforce embankments, to aid in construction of steep slopes, to reinforce earth and rock dams, to stabilize slopes temporarily, to anchor facing panels in reinforced earth walls, to aid in bearing capacity of shallow foundations.

5.1.3 Filtration Function of Geotextiles

Beneath stone base for paved or unpaved roads and airfields, beneath ballast under railroads in place of granular soil filters, around perforated underdrain pipe, to filter hydraulic fills.

5.1.4 Drainage Function of Geotextiles

As a chimney drain in an earth dam, as a drain behind a retaining wall, as a drain behind railroad ballast, as a drain for roof gardens.

5.2 Geonets

Water drainage behind retaining walls, water drainage beneath sport fields, water drainage beneath building foundations, water drainage or frost-susceptible soils.

5.3 Geomembranes

Liners for portable water,reserve water and waste liquids, liners for water conveyance canals, liners for waste conveyance canals, covers for solidwaste landfills, water-proofing within tunnels.

5.4 Geogrids

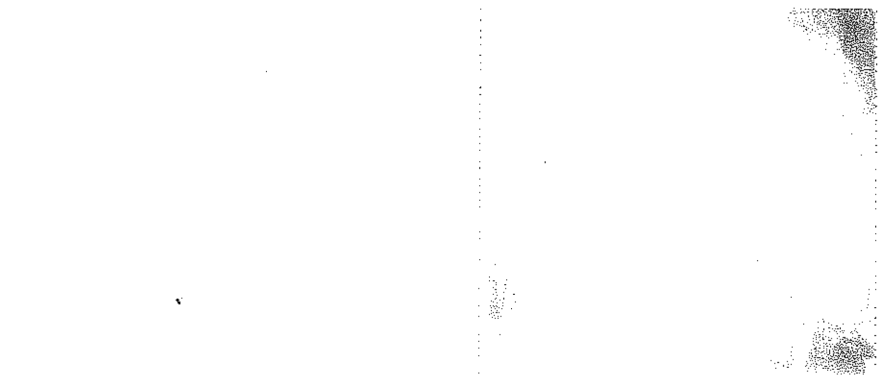
Beneath aggregate in unpaved roads, beneath ballast in railroad construction, reinforcement of embankment fills and earth dams, as gabions for wall construction, as asphalt reinforcement in pavements, as inserts between a geotextile and a geomembrane.

5.5 Geosynthetic Clay Liners

Beneath a geomembrane in the cover of a landfill, above geomembranes as puncture protection against coarse gravel, as single liners for canals.

5.6 Geopipes

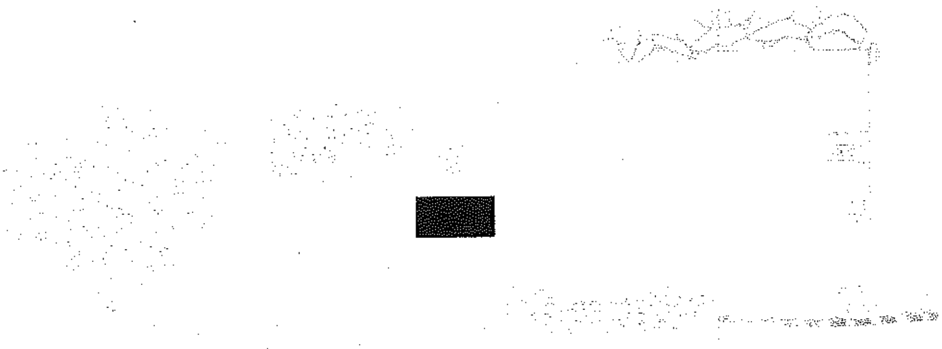
Highway and railway edge drains, seepage drains in tunnels, pore water drains behind retaining walls, interceptor drains in seeping slopes, pipes used in dewatering projects, waste water drainage systems[1].



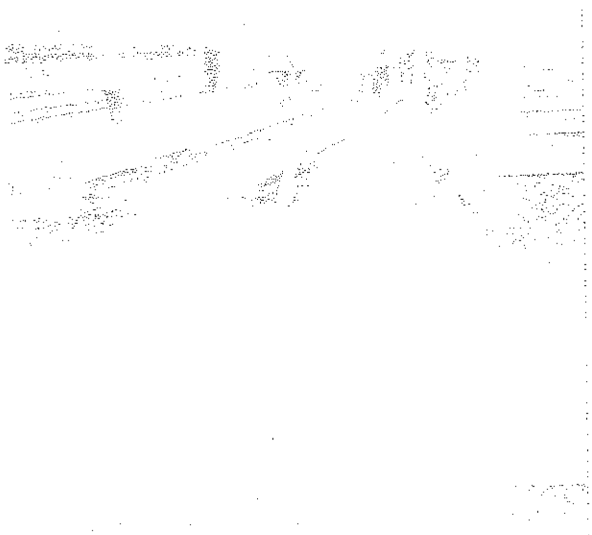
(a) (b)

1 a Placing a geotextile in the ground as a protective and drainage layer[5],
1 b Road tunnel[5].

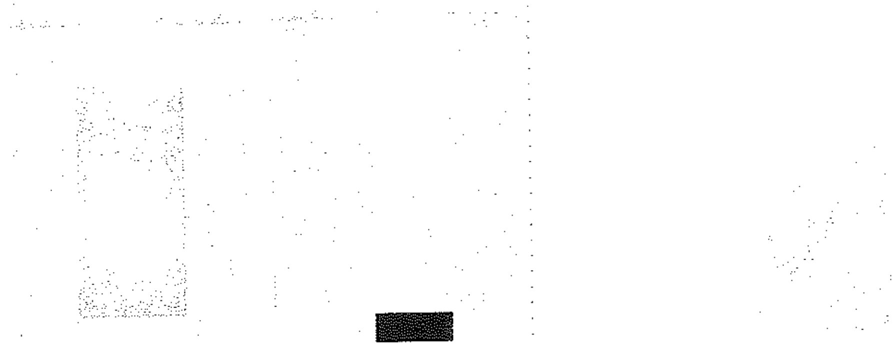
2 In ground improvement by preloading, usage of geotextile as a top drainage cover[5].



3 Taking this road surface as an example, we can see that water-logged subsoil has contaminated the aggregate layer, causing it to disperse. The introduction of a layer of geotextile separates the aggregate from the subsoil, spreading the stress and improving soil compaction under load. A much thinner layer of aggregate is required and the stability of the fabric ensures that the aggregate itself remains undisturbed[6].

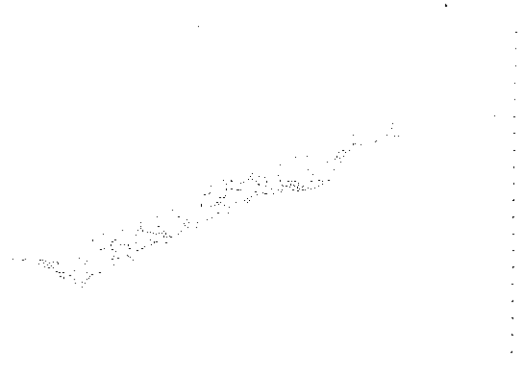


4 Usage in highway construction[5].



5 a It is designed for use in all types of drainage and filtration projects. Its high permeability allows rapid water elimination and faster soil consolidation. Also considerable cost savings can be made through its use. In this conventional drain, for example, expensive well graded aggregate is used to prevent piping of fine soil particles. By using geotextile as a filter lining, it is possible to replace graded filter material with cheaper, coarse aggregate and, at the same time, increase permeability[6].
5 b In side drainage of a road system, as a usage of layer surrounding coarse, unskilled, granular material[5].

6 a The usage of geosynthetics to stabilize embankments and retaining walls[6].
6 b Nearly vertical retaining wall applications with geotextile[5].



7 Using of geotextiles provides a low-cost solution wherever water structures such as dams, coastal reinforcements and reclaimed land need protection against erosion and the effects of hydraulic pressure. In this example, geotextile is laid and anchored above the soil surface of the sea embankment and layers of riprap piled on top. This is sufficient to prevent any piping away of the soil of the embankment[6].

6.CONCLUSION AND DISCUSSION

The most important property of geosynthetics ,having a lot of application areas, is being economic in time saving and cost. On the other hand, its quality is safe till 100 years. When the life of the engineering construction thought to be 70 years, the economics of geosynthetics is well understood. Also, qualified workmanship is not needed in application.

REFERENCES

1. Koerner R. M. (1994), *Designing with Geosynthetics*, Third edition, 783 pages, Prentice Hall, New Jersey, USA.
2. Wasti Y. (1992), *İnşaat Mühendisliğinde Geotekstil ve Geomembran Uygulamaları Eğitim Semineri*, 16-17 Nisan, ODTÜ-Sem, Ankara, Türkiye.
3. Yılmaz H. R. (1998), *Zemin İyileştirme Yöntemleri Ders Notları*, Ege Üniversitesi, İzmir, Türkiye.
4. Hausmann, M. R. (1990), *Engineering Principles of Ground Modification*, McGraw-Hill, Singapore.
5. *Design and Practice* (1986), Linz, Austria.
6. *Muhtelif Firma Broşürleri*.

MEASUREMENT TECHNIQUES OF THE HEAT RESISTANCE ON THE NON-WOVEN

M.Köstem, K.Yıldırım, N.Ogan and N.Aydın
TÜBİTAK-Bursa Test ve Analiz Laboratuvarı (BUTAL)

The heat insulation and transfer are important phenomena about several places such as home insulation, hot water transfer, hot water storage etc. Although for this aim many materials are used,using non-woven fabrics are state of art..

It is known that the non-woven fabrics are used for the aim of heat and sound insulation especially in car industry.

The non-woven fabrics are universally defined; textile fabrics made of a fibrous layer which may be a carded web, a fiber web, a system of random laid or oriented fibers or threads, possible combined with textile or non-textile materials such as conventional textile fabrics, plastic films, foam layers, metal foils etc. and forming with them a mechanically or chemically bonded textile product. The non-woven fabrics may be produced as a 2.dimension (paper, membrane filter) or 3. Dimension (Filter fabrics, pads, insılator non-wovens) product. There are several production techniques of non-woven as seen below

- Wet proses,
- Dry proses.
- Reinforced fiber web,
- Directly from thermoplastic polymer melt,

TÜBİTAK – BUTAL which serve as a test and analysis laboratory to the industry of textile, environment, chemistry and food has involved making tests and analysis service for the technical textiles, which production and using range has expanded in its mission and vision. With this aspect, technical textiles' tests and analysis have been made and also the new methods are being applied in our laboratory. According to this new approach our laboratory has produced a heater and installed a system to measure the heat resistance coefficient of the non-woven fabric as a result of a client requests.

The heat conduction occur in three ways;

- Convection
- Conduction
- Radiation

According to our theoretical investigation the measurement of heat transfer could be made by two ways, one of these is under one plate and the other is between two plates.

At this research to measure the heat resistance coefficient we use a system which principle is to measure heat conduction between two plate according to conduction heat transfer under steady state.

Having made the test we transfer the test value to the computer to measure the heat resistance coefficient. We write a program run under Microsoft Excel to calculate it.

The using equipment for this test are;

- A Oven run under steady state and monitoring the current and given temperatures,
- A thermo couple.

We use the universal heat transfer equation to calculate the heat resistance coefficient. This equation is valid only steady state heat transfer

$$Q : k \cdot A \cdot \frac{t_2 - t_1}{l}$$

Q: Amount of heat transfer

k: heat transfer coefficient

A: the area

t_1: the temperature on the one surface on material

t_2: the temperature on the other surface on material

l: Thickness of material

We want to expand this test to other area such as metal industry, apparel industry.

REFERENCES

1. K.Gieck, E.Y. Alıcı, " Mühendislik Formülleri", 1982, Ankara.
2. E.R.G. Eckert, R.M. Drake, "Analysis of heat and mass transfer".
3. V.M.Faires, " Thermodynamics of Heat Power".
4. R.Krcma, "Manual of nonwovens".

CONVEYOR BELT FABRICS

H. Özdemir
Dokuz Eylül UniversityTextile Engineering Dep., Izmir

INTRODUCTION

Mass production in industry depends on transport capacity. Mass which is produced by machines is transferred, so order of cycle will be continued. One of the important porters is conveyor belts.

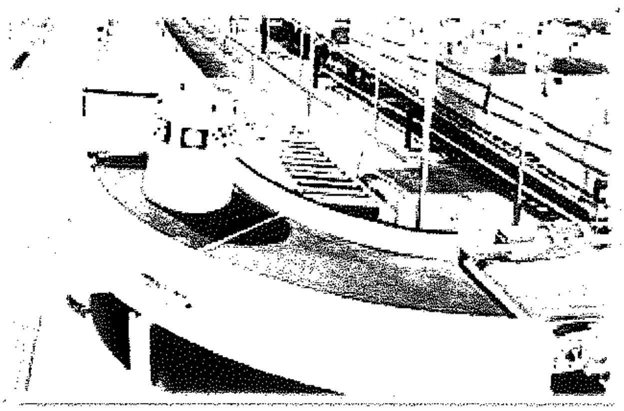
Conveyor belts are used in transferring unit weights, cast materials and light mid-products which are manufactured at various departments from one process to another process along the production line. Great amount of piled materials are transported continuously to far distances by conveyor belts. Conveyor belts are suitable for transferring abrader materials such as sand, coke and rock. In addition to this, conveyor belts are used for passenger and cargo transporting in airports and shopping centers (Figure 1a and 1b). According to their designs, conveyor belts are classified as stable, movable and active. They can be categorized into two groups as general and special purpose, according to their purposes.

Owing to increase in belt strength, transfer distance become long. It is possible to carry loads in high capacity (500-500 m^3/s or more) to long distance (from 1-2m to 13000 m). Running temperatures for normal conveyor belts are between –20 and 125 °C, and for special synthetic conveyors are between –45 and 540 °C (7,8).

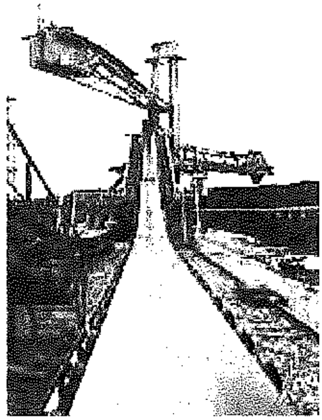
1. STRUCTURE OF CONVEYOR BELTS

Conveyor belts consists of woven fabric that is coated on one or both sides with a man made or natural rubber. With the lamination process, many process, many layers of fabrics and other substrates can be combined.

A coated fabric is a composite textile material where the strength characteristics and other properties are improved by applying a suitably formulated polymer



(a)



(b)

Figure 1. The uses of conveyor belts.

composition. The selection of fiber and fabric for coating depends on the type of coating and end-use performance requirements. Textile or steel cords are used to reinforce rubber or plastic in conveyor belts and to provide longitudinal strength. In return, rubber and plastic covering protects textile materials from damage, moisture. Depending on the application area, the major property requirements of conveyor belts are high strength and flexibility, low stretch in service, abrasion, impact and tearing resistance, temperature and fire resistance, long life, resistance to moisture, oils and chemicals. To obtain these properties, appropriate fiber, fabric and polymeric covering compounds are required. Good adhesion of the reinforcing plies is essential.

The schematic of structures which consist of conveyor belt are shown in Figure 2. These structures are: 1. Carcass, 2. Coating rubber, 3. Connective, 4. Protective fabric.

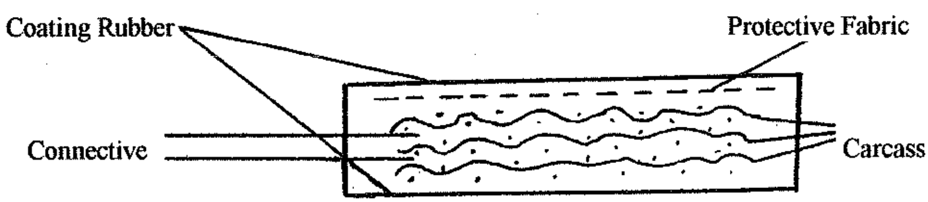


Figure 2. The structure of conveyor belt.

All of the woven fabrics that are in middle of belt are called carcass. Carcass is exposed to loads that result from tension, transmit drawing force, so it causes belt to convey loads. This structure are generally consisted of one or a few layers. The rubber which are between carcass layers bounds these layers to each other.

The main property of carcass is that it provides maximum resistant structure by yarns or cords. The most important property of woven layers is minimum drawing forces that are in weft and warp direction.

2. FIBERS USED IN CONVEYOR BELT FABRICS

Strength, extension and flexibility of synthetic fibers that are used in technical woven fabrics are higher than natural fibers that were used earlier. Major fibers used in the rubber industry are cotton, viscose rayon, nylon, polyester, glass and aramid. The major fiber properties required in rubber reinforcement are:

- High tenacity and modulus
- Good dimensional stability
- Moisture resistance
- Resistance to high temperature
- Fatigue resistance
- Good bonding with adhesives and rubber

In carcass, high tenacity fibers are used. They are produced with hot-cold stretch and extension techniques. The main aim of the process is development of polymerization and fiber molecule orientation.

2.1 Cotton

Fabrics made of cotton are the traditional base material used in coating. This trend has declined because of synthetics whose tenacities are high. Pamuk is preferred due to the availability and to the excellent coating adhesion imparting dimensional stability to fabric. The disadvantages of cotton are low extensibility, poor rot, acid and weather resistance, flex cracking and limited impact resistance. Cotton has medium abrasion resistance. Size material is normally removed from the cotton fabric prior to coating. Cotton is also blended with polyester for coated lighter weight fabrics having improved wear characteristics.

2.2 Rayon

Although rayon gives higher tearing strength than cotton, its use for carcass is declining. The main disadvantage of rayon fabric, including high tenacity fabrics, is that it has poor wet shrinkage and low weather resistance.

2.3 Nylon

Nylon, due to its higher strength, has many advantages over cotton and rayon fabrics. Fabrics made of nylon have high abrasion resistance, tear and tensile strength. Nylon is widely used for lighter weight coated fabrics as it imparts higher strength, toughness, flexibility, waterproofness and durability. Filament nylon fabrics can be coated as gray fabric. A pretreatment which is usually solvent based, is applied to fabric to improve the adhesion of coating compound. Due to the environmental reasons, the solvent based pretreatment is replaced with a water based system.

2.4 Polyester

Polyester has high modulus, low extensibility and low rate of stress decay. Owing to its' high chemical, weather and abrasion resistance, use of polyester in coating applications is increasing. Although the abrasion resistance somewhat lower than the nylon, it gives flexible tough coatings similar to nylon and has high tensile and tear strength. The improved priming methods and improved yarn manufacturing give better adhesion of coating compound to polyester and improved dimensional stability.

2.5 Acrylics

Only small usage of acrylic fabrics is found in the coating market. Acrylic fabrics are used where outstanding weather resistance properties are required. The mechanical properties of the modified acrylics limit its application in the coating field. Acrylics have low thermal stability and low abrasion resistance.

2.6 Polypropylene

Polypropylene has excellent mechanical properties under normal conditions but has poor thermal stability. Polypropylene has high stress decay and poor coating adhesion which limits its use.

2.7 Aramid

Because aramid tenacity is 7 times as steel tenacity and aramid is lighter than steel, aramid are used instead of steel in most applications. When it is exposed to flame, it does not melt. When flame is taken away, it will be out. Aramid resists to temperature of 400-500 °C, to damp and to chemicals. Aramid has high abrasion resistance.

3. FABRICS USED IN CONVEYOR BELTS

3.1 Carcass

It is possible that yarns (warp) that provide strength longitudinally and yarns (weft) that provide strength transversally are woven to obtain required strength at various types. In Table 1, the coding of fabrics according to fiber types is seen.

Table 1. The coding of fabrics according to fiber types (6).

Codes	Yarn Type	
International	Warp	Weft
B	Cotton	Cotton
R	Cotton	Rayon
Pb	Nylon + Cotton	Nylon + Cotton
Eb/Pb	Polyester + Cotton	Nylon + Cotton
Pz	Nylon + Textured	Nylon + Textured
RP	Rayon	Nylon
PP	Nylon + Rayon	Nylon + Rayon
P	Nylon	Nylon
EP	Polyester	Nylon
EP/P	Polyester + Nylon	Nylon
AP	Aramid	Nylon
Ab/Pb	Aramid + Cotton	Nylon + Cotton
ST	Steel	-

Belt types are classified according to carcass types in Table 2.

Table 2. Belt types, according to carcass types (6).

Textile Carcass Belts	Steel Cord Belts
Bands with Cotton Fabric	Steel Cord Bands
Bands with Polyamide Fabric	Steel Weave Bands
Bands with Polyester Fabric	
Bands with Aramid Fabric	

3.1.1 Textile Belts

Basic weaves such as plain and matt are used frequently in conveyor belts. Special weaves may be used to improve the physical characteristics such as stretch, edge wear and tear. Two or three-layer solid fabrics provide dimensional stability.

Blending different fibers in fabrics offers many advantages including improved adhesion, strength, impact resistance, fatigue resistance, stretch resistance, temperature and chemical resistance. Typical fiber combinations include aramid or polyester warp and nylon weft, nylon warp and weft. For bulk and adhesion, cotton and synthetic staple fibers added.

3.1.1.1 Square Weave Fabrics

Suitable square weave fabrics are plain, twill, matt and broken weaves.

Plain

Perfect bindings of weft and warp threads in plain weave that is the most simple weave, consist of strong weave fabric. When number of bindings and intersections decrease, fabric will be more looser. This is not seen at plain weave. Fabric flexibility is low, because of full binding. Yarns with low twist are used to obtain a crisp and flat surface from this construction.

Twill

By twill weave, the most heavy weighted fabrics can be woven, because; yarns are close to each other. Floatings that are in twist fabrics, slide over each other, so these fabrics are elastic in twill line direction which floats arrange side by side. As this kind of flexibility increase fabric resistance to sudden stretch, this feature is suitable for conveyor belts. At twill weave, by warp superior structure, mechanical elongation can be reduced. Since the number of intersections in unit surface is decreased, fabric tenacity will increase.

Matt

It provides soft and smooth fabric surface. When floating length is bigger than 4, fabric structure will be loosen and floating yarns will swell up, so big unit-matt weave should be used carefully.

Broken Weave

They are twill derivatives that are obtained from by skipping some intersections. There are keen interruptions and fractures in twill lines.

Technical values, according to DIN 22102, for different types of carcass are given in Table 3 and 4.

Table 3. Technical properties of PP (polyamide-polyamide) fabrics (3).

Lengthwise Tenacity(kg/cm)	70	100	125	160	200	250
Breadthwise Tenacity (kg/cm)	35	50	50	65	80	80
Unit Weigth (g/m^2)	250	360	420	520	650	760
Thickness (mm)	0.5	0.6	0.65	0.85	1.1	1.2
Warp Threads -Yarn Type	Ny 66	Ny 66	Ny 66	Ny 66	Ny 66	Ny 66
-Yarn Number (dtex)	940×1	1400×1	940×2	1400×2	1880×2	1880×3
-Twist (tpm)	160	160	120	120	100	60
-Setting (warp/dm)	140	134	124	112	100	84
-Extension (%)	23	23	25	25	27	27
Weft Threads -Yarn Type	Ny 66	Ny 66	Ny 66	Ny 66	Ny 66	Ny 66
-Yarn Number (dtex)	940×1	1400×1	940×2	1400×2	1880×2	1880×2
-Twist (tpm)	160	160	120	120	100	100
-Setting (weft/dm)	70	74	56	43	40	40
-Extension (%)	32	32	32	32	34	34

Table 4. Technical properties of EP (polyester-polyamide) fabrics (3).

Lengthwise Tenacity(kg/cm)	70	100	125	160	200	250	315	400
Breadthwise Tenacity (kg/cm)	35	50	50	65	80	80	80	80
Unit Weigth (g/m^2)	260	355	430	550	685	860	990	1320
Thickness (mm)	0.5	0.55	0.70	0.90	1.05	1.2	1.3	1.7
Warp Threads -Yarn Type	PES	PES	PES	PES	PES	PES	PES	PES
-Yarn Number (dtex)	1100×1	1100×1	1100×2	1100×3	1100×4	1100×6	1100×5	1100×6
-Twist (tpm)	150	150	120	120	100	70	80	80
-Setting (warp/dm)	140	195	120	110	100	87	124	142
-Extension (%)	17	18	18	18	18	18	20	18
Weft Threads -Yarn Type	Ny 66	Ny 66	Ny 66	Ny 66	Ny 66	Ny 66	Ny 66	Ny 66
-Yarn Number (dtex)	940×1	940×1	940×2	940×3	940×4	940×4	940×4	940×4
-Twist (tpm)	160	160	120	120	100	100	100	100
-Setting (weft/dm)	72	95	58	43	40	40	40	40
-Extension (%)	28	28	28	30	30	32	32	32

3.1.1.2 Cord Fabric

The functional part is warp threads which are exposed to loads. Weft yarns do not have function. They are cotton yarns whose tenacity are low with respect to warp threads. Yarn type and twist are the most important factors in resistance of cord fabrics. Warp settings are under the normal settings, which are 6-8-10-12-14 /10 cm. Appearance of cord fabrics are similar to fishnet.

3.1.1.3 Aramid Cord Fabric

Aramid fibers are directional fibers that can be alternative to steel fibers. They provide strength and low extendibility with belts. Conveyor belts with aramid carcass are lighter and more resistant than steel reinforcement belts. Aramid carcasses can be used in bigger length than heavy steel cord-bands' length. The cross section drawing of aramid cord fabrics with straight warp is seen in Figure 3 and properties of these fabrics are given in Table 5.

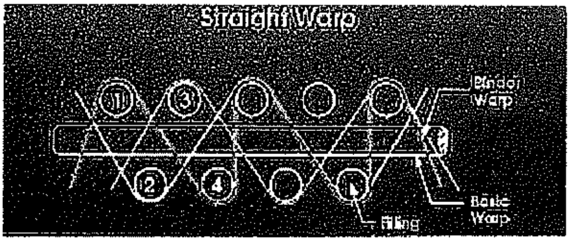


Figure 3. The cross section drawing of aramid cord fabrics with straight warp (8)

Table 5: Properties of aramid cord fabrics with straight warp (6)

Class	Tensile Strength Warp (N/mm)	Tensile Strength Weft (N/mm)	Fabric Weigth Dipped (g/m^2)	Gauge (mm)
DPP 500	630	120	1255	1,80
DPP 630	800	150	1385	2,10
DPP 800	970	180	1480	2,30
DPP 1000	1200	180	1600	2,70
DPP 1250	1600	180	1900	2,90
DPP 1400	1800	180	1970	3,35
DPP 1600	1900	180	2250	3,35
DPP 1800	2200	180	2425	3,40
DPP 2000	2400	180	2800	3,45
DPP 2500	3000	180	3115	3,50

3.1.1.4 Rigid Woven Carcasses

In figure 4 , schematic of a rigid woven carcass are shown. A set of fabrics, generally 2,3 or 4 fabrics, which are woven together, consists of rigid woven structure. Simple rigid woven fabrics are obtained from plain or twill fabric layers which are compressed up to drawing strength.

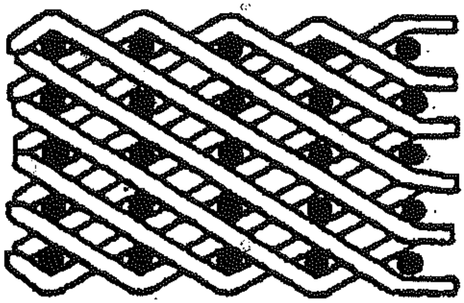


Figure 4. Schematic of a rigid woven carcass (2).

Pressure can be applied to rigid woven carcass. They are coated with PVC that resistant to flame. Belt consists of one part and there is not risk of layer separation. Their extension is low. Their cracking and breaking are difficult. They can be added by adhering easily. They are suitable for damp and hard working conditions. In Table 6, technical properties of conveyor bands with rigid woven carcass are given.

Table 6. Technical properties of conveyor bands with rigid woven carcass (8).

Class	Maximum Belt Tension (N/mm)	Belt Thickness (mm)	Belt Weigth (g/m^2)
3500	61	7,90	7914
4000	70	8,65	9164
5000	88	9,40	9580
6000	105	9,90	10413
8000	140	10,70	11663

3.1.2 Steel Belts

3.1.2.1 Steel Cord Belts

As in other conveyor bands, steel rope-bands are comprised of a drawer component and protector layer which envelopes steel ropes. Steel wires are arranged in a plain, side by side as a drawer component. Protector layer is composed of rubber mix which is suitable for various conditions. This kind of belts can become hollow even at narrow widths.

Band length can be bigger. Their stretch distances are short, because of their low extension. A long band has longer life than a few numbers of bands that run at the same position. Strength values of steel cord belts, according to DIN 22131, are given in Table 7.

Table 7. Strength values of steel cord belts (4).

Type	St 1000	St 1250	St 1600	St 2000	St 2500	St 3150	St 4000
Min. Breaking Strength (kg/cm)	1000	1250	1600	2000	2500	3150	4000

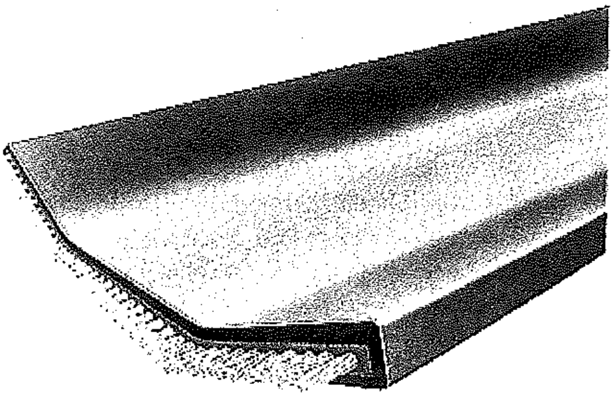


Figure 5. Steel Cord Belt (8).

3.1.2.2 Steel Weave Belts

The production of these type of bands are grouped into 3 category namely textile weft-band (TW), impact resistant weft-band (IW) and strong weft-band (SW). In Table 8, impact resistant weft-bands' technical data and in Figure 6, picture of impact resistant weft-carcass are seen.

Table 8. Impact resistant weft-bands' technical data (8).

Type	**Belt Tension (N/mm)**	**Tensile Strength (N/mm)**	**Belt Modulus (N/mm)**
IW630R	79	500	31534
IW800R	100	801	40118
IW1000R	125	1003	50104
IW1250R	156	1253	62543
IW1600R	200	1603	80062
IW2000R	251	2006	100033

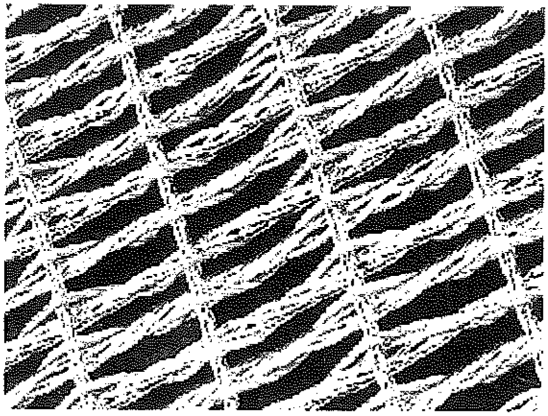


Figure 6. Picture of impact resistant weft-carcass (8).

3.2 Protector Fabrics

Protector fabrics that are called shock textile or shock absorbent are used in conveyors that are loaded with big masses in a stroke manner. They protect the carcass against impacts. They increase the conveyor's abrasion resistance. The important properties of protector fabric are:

- Tenacity
- Abrasion Resistance
- Well arranged in lengthwise and breadthwise direction
- High extension

Protector fabric does not contribute to conveyor strength, carcass takes tension forces. Nylon is the most common fiber. Protector fabrics are two types.

3.2.1 Leno Fabrics

This fabrics have different weaves from plain, twill and sateen weaves. Two kinds of warp threads required for this weave, namely ground warp threads and crossing warp threads. Crossing warp threads have special healds, and move both up and down wards and also come cross with ground warps and each other, so connection is made. At full-leno weaves, ground warps also come cross. In Figure 7, schematic of an example of leno weave is seen.

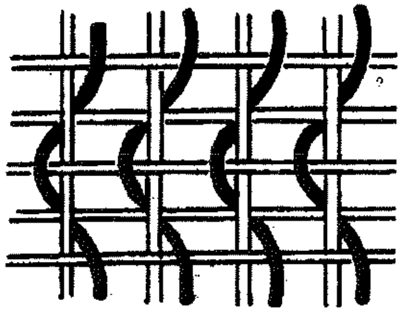


Figure 7. Schematic of an example of leno weave (2).

3.2.2 Square Weave Open Structure Fabrics

It is a loose weave, because plain weave that has perfect intersections is used. It is placed under top cover to bind it well to the carcass. Required properties for square weave open structure fabrics are equal warp and weft thread tensions, forming squares by the intersections of two sets of yarns at right angles, few mistakes, high tenacity and flexibility and also good adherence to rubber paste.

4. POLYMERS AND ADDITIVES IN CONVEYOR BELTS

The coating polymer or blends of polymers are selected based on the end-use application. As the need arises, the coating compounds are often modified with addition of newer chemicals to meet the end-use performance.

The base polymer for coating can be natural or synthetic rubber or rubber-like polymers. High polymeric materials such as cellulose ester and ethers, polyamides, polyesters, acrylics, vinyl chloride, vinylidene chloride, polyurethanes and natural and synthetic elastomers and rubbers are used in compounding.

The mixing operation of various chemicals to produce the coating compound is commonly known as the compounding operation. The choice of compounding chemicals and fillers are governed by end product requirements. Besides polymers, resins and fillers, other additives such as fire retardants, thickeners and coloring agents may be included in coating formulations.

5. COATING METHODS OF CONVEYOR BELTS

A number of rubberized textile reinforcement plies are laminated, consolidated and vulcanized in special presses and curing machines to form conveyor belts, and are became vulcanite. Usually three or six plies are used for reinforcement. Increasing the number of plies unnecessarily reduced the ratio of total ply strength to belt strength.

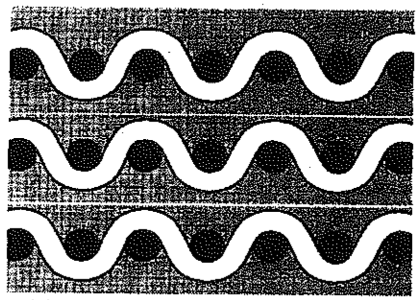


Figure 8. Schematic of multi-ply fabric reinforced conveyor belts (1).

Fabrics are coated, when they are hot. Calendering is a coating process in which the large difference between the fabric and the rubber sheet at the nip of the calender forces the rubber into the fabric weave (Figure 9). In calendering, both sides of the full width fabric are coated simultaneously. Fabrics are dried to avoid blowing of the laminate during vulcanization. Fabrics are passed over a multiple steam heated drum drier or hot plate. Then, fabrics are cut to the width desired. The cut widths are passed through a doubling machine to adhere the layers together until the desired number of plies is obtained. To make the belt endless, the ends of the belt are brought together either by mechanical fastening or splicing. Splicing is done by vulcanizing the belt ends together. Passenger and package carrying belts are covered with PVC.

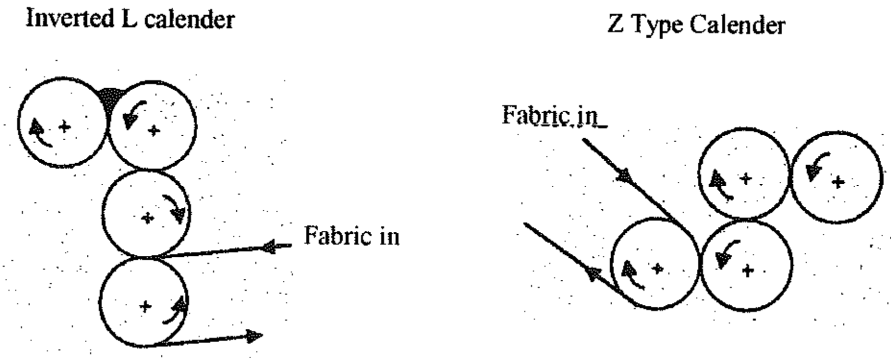


Figure 9. Schematic of calender coating (1).

REFERENCES

1. Adanur, S., Wellington Sears Handbook of Industrial Textiles, Technomic Publishing Co. Inc., PA, USA, 1995.
2. Başer, G., Dokuma Tekniği ve Sanatı, Cilt 1: Temel Dokuma Tekniği ve Kumaş Yapıları, TMMOB Tekstil Mühendisleri Odası Yayınları, No:2, İzmir, Türkiye,1998.
3. DIN 22102, Fördergurte mit Textileinlagen, Teil 1, Deutsches Institut für Normung e.V., April 1991.
4. DIN 22131, Stahlseilgurte für die allgemeine Fördertechnik, Teil 1, Deutsches Institut für Normung e.V., November 1988.
5. Lennox-Kerr, P., Flexible Textile Composites, The Textile Trade Press, Manhester, 1973.
6. http://www.olbo.de
7. Proposed Requirements for the Approval of Flame-Resistant Conveyor Belt Rule, Office of Standards, Regulations and Variance Mine Safety and Health Administration, U.S., December, 1999. (http://www.msha.gov/REGS/FLEX/conveyorria.pdf)
8. http://www.scandura.net/
9. Standard for Conveyor Belt Covers, H. Simonsen Consultant, Sept. 1990 Manager R & D, Germany, Sept. 1990. (http://www.saimh.co.za/beltcon/beltcon6/paper613.htm)

IST INTERNATIONAL TECHNICAL TEXTILES CONGRESS

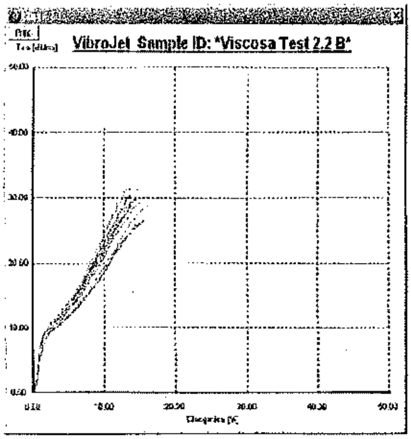
11-12 OCTOBER 2002

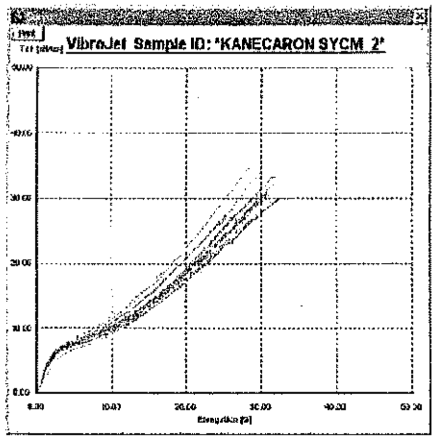
We apologize for the errors occured during publishing.

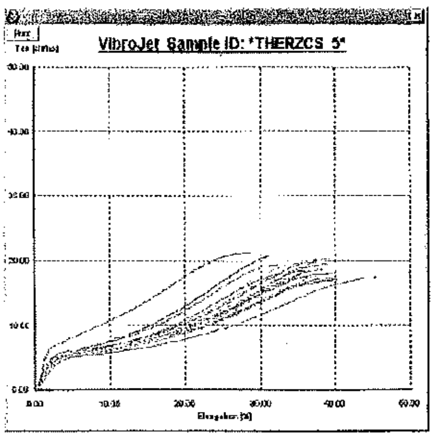
Organizing and Executive Commitee

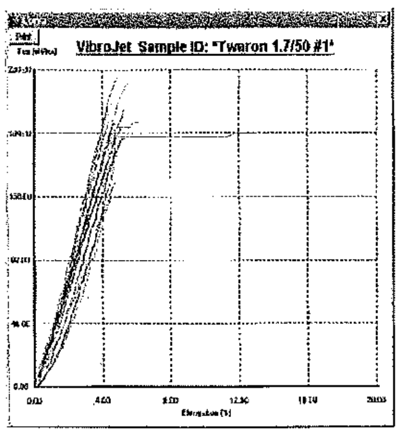
HIGH TECH AND FLAME RETARDANT FIBRES MANUFACTURING TECHNOLOGIES IN THE TEXTILE PROCESS

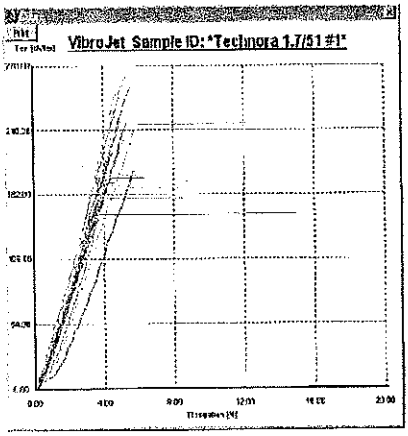
A. Piccolini , E.Antisso
Fil Man Made Group, Italy

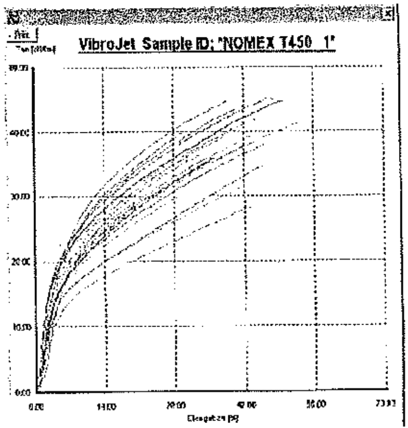


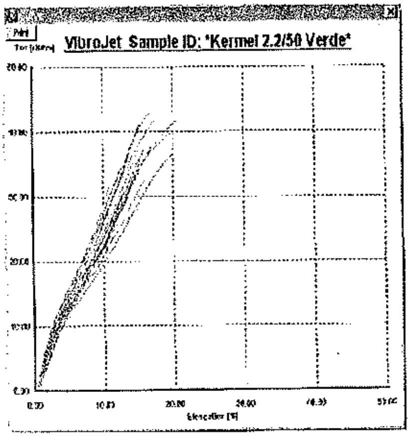


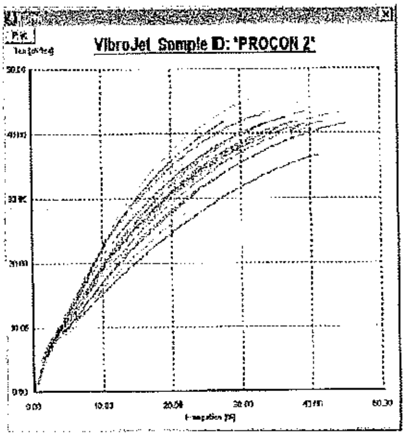


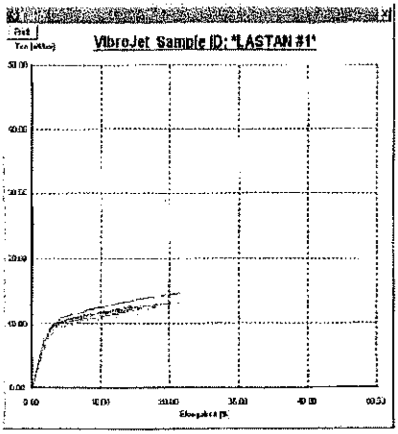



VibroJet Sample ID: "Technora 1.7/51 #1"
Elongation [%]


VibroJet Sample ID: "NOMEX T450 1"
Elongation [%]


VibroJet Sample ID: "Kermel 2.2/50 Verde"
Elongation [%]


VibroJet Sample ID: "PROCON 2"
Elongation [%]


Print
VibroJet Sample ID: "LASTAN #1"
50.00
40.00
10.00
0.00
0.00
10.00
20.00
30.00
40.00

SEARCHING THE USAGE OF MEDICAL TEXTILES IN PERIPHERIC NERVE TISSUE DAMAGES AS REINFORCED GRAFTS

N.Yıldız
Pamukkale University Textile Engineering Department, Denizli

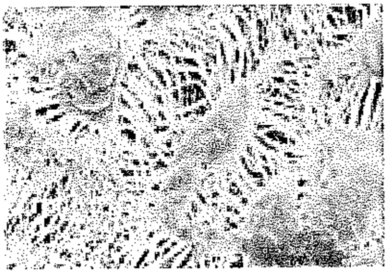


Figure 4. Gore-Tex PTFE Biomaterial[6]

Figure 5: Teflon Mesh Biomaterial[6]

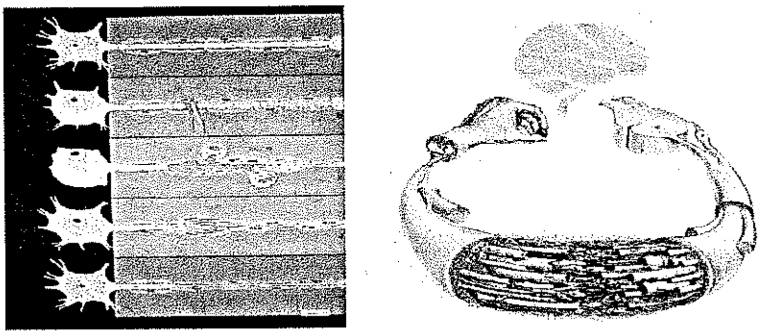


Figure 8. Nerve Regeneration and Repair Using Silicone Regeneration Chamber Model [11]

MULTIAXIS THREE DIMENSIONAL WOVEN FABRICS FOR COMPOSITES

K.Bilişik
Erciyes University, Faculty of Engineering, Textile Eng. Dep., Kayseri

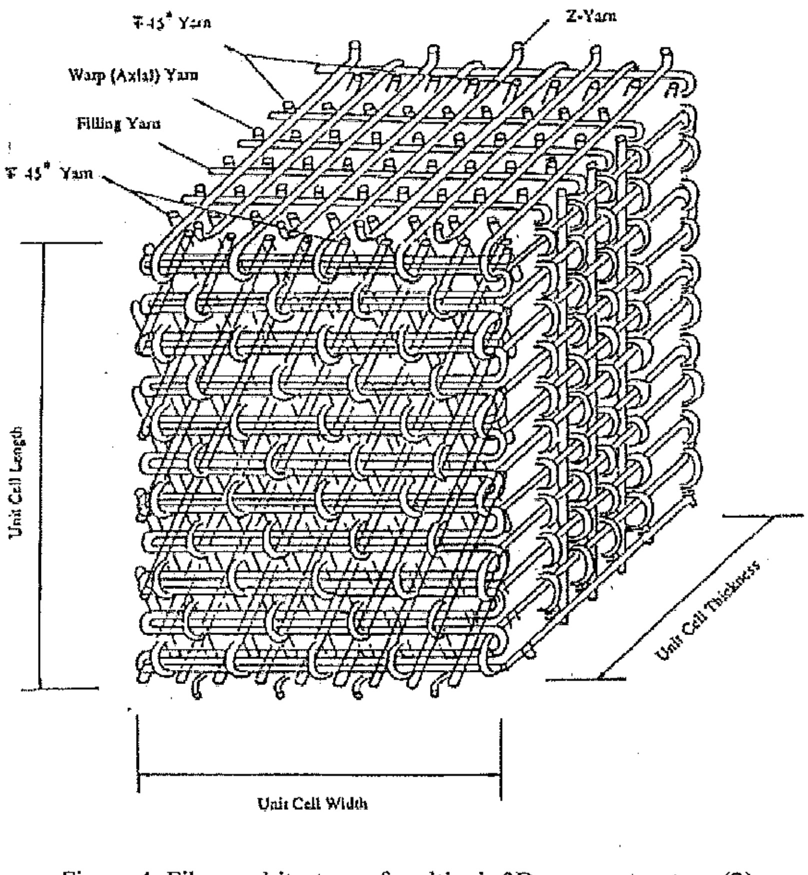


Figure 4. Fiber architecture of multiaxis 3D woven structure (2).

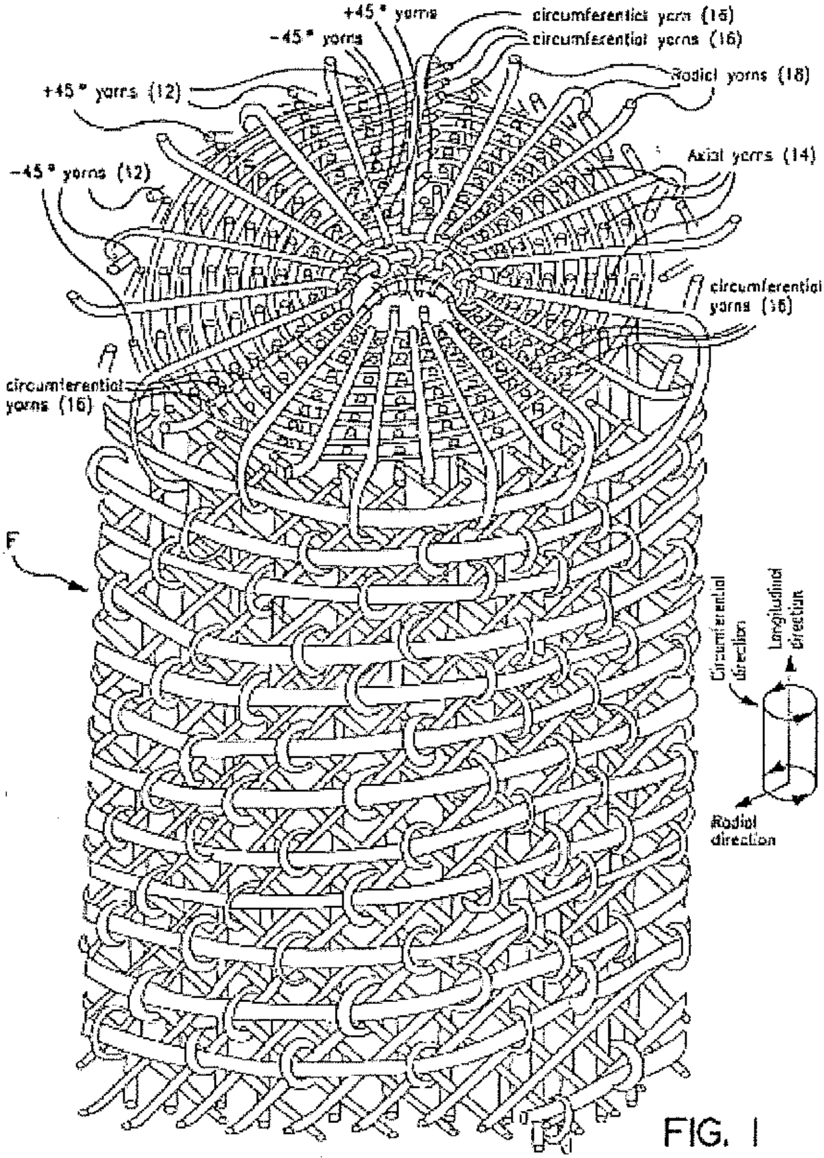
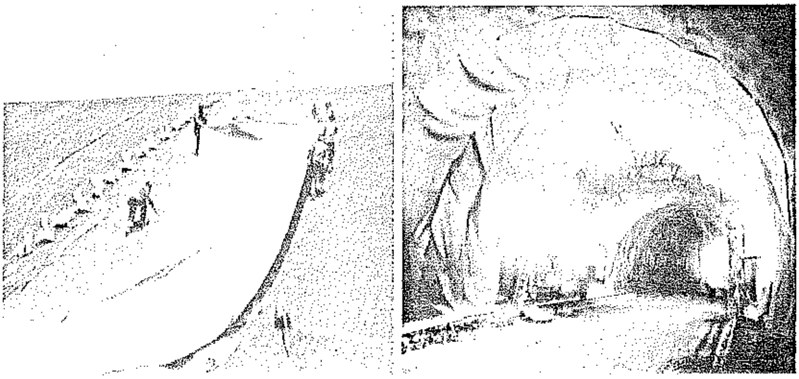


FIG. 1

Figure 5. Fiber architecture of multiaxis 3D circular woven structure (3,4).

GEOSYNTHETICS AND COMMON USAGE IN ENGINEERING STRUCTURES

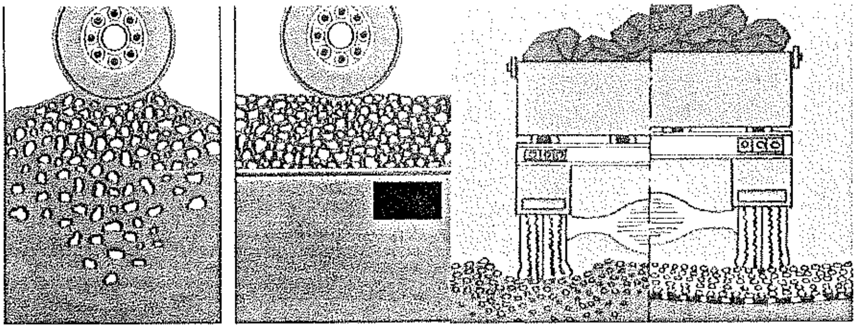
H. R. Yılmaz, R.A. P. Aklık, R.A. T. Eskişar
Ege University, Engineering Faculty,Civil Engineering Department, İzmir



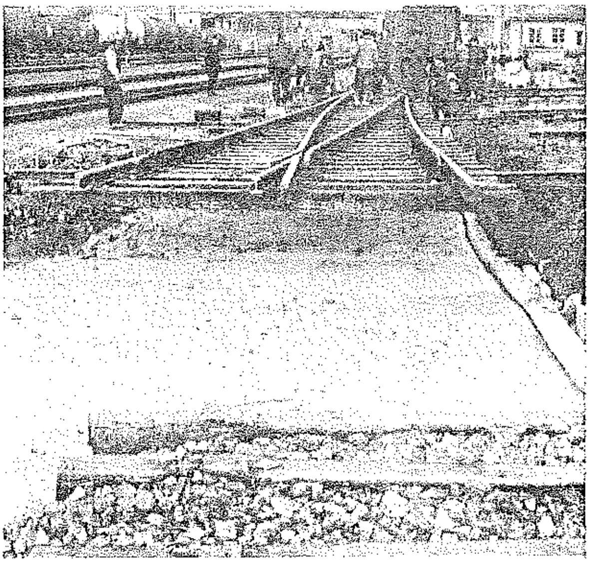
(a) (b)

1 a Placing a geotextile in the ground as a protective and drainage layer[5],
1 b Road tunnel[5].

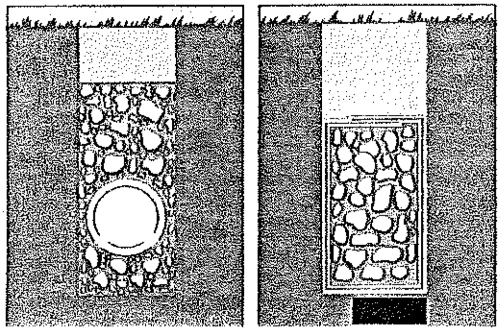
2 In ground improvement by preloading, usage of geotextile as a top drainage cover[5].



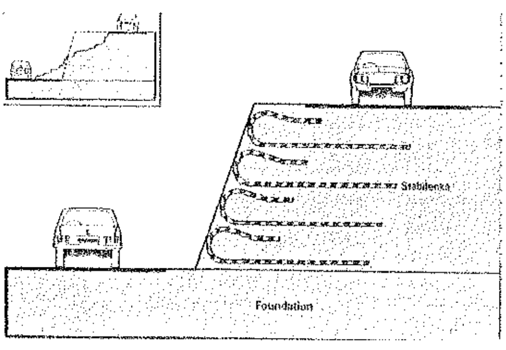
3 Taking this road surface as an example, we can see that water-logged subsoil has contaminated the aggregate layer, causing it to disperse. The introduction of a layer of geotextile separates the aggregate from the subsoil, spreading the stress and improving soil compaction under load. A much thinner layer of aggregate is required and the stability of the fabric ensures that the aggregate itself remains undisturbed[6].

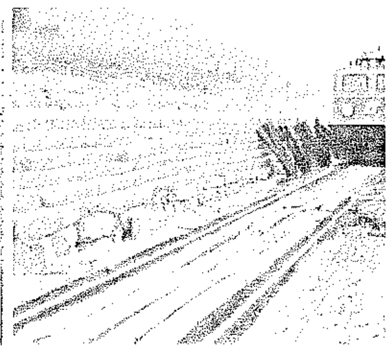


4 Usage in highway construction[5].

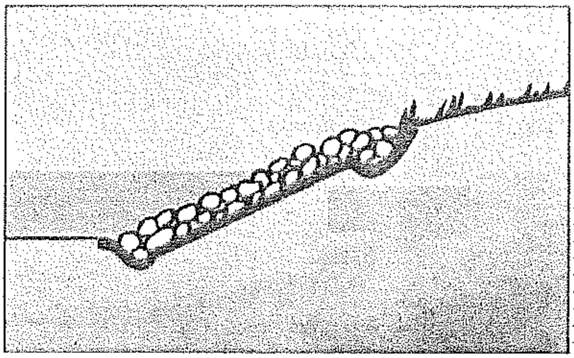


5 a It is designed for use in all types of drainage and filtration projects. Its high permeability allows rapid water elimination and faster soil consolidation. Also considerable cost savings can be made through its use. In this conventional drain, for example, expensive well graded aggregate is used to prevent piping of fine soil particles. By using geotextile as a filter lining, it is possible to replace graded filter material with cheaper, coarse aggregate and, at the same time, increase permeability[6].
5 b In side drainage of a road system, as a usage of layer surrounding coarse, unskilled, granular material[5].





6 a The usage of geosynthetics to stabilize embankments and retaining walls[6].
6 b Nearly vertical retaining wall applications with geotextile[5].



7 Using of geotextiles provides a low-cost solution wherever water structures such as dams, coastal reinforcements and reclaimed land need protection against erosion and the effects of hydraulic pressure. In this example, geotextile is laid and anchored above the soil surface of the sea embankment and layers of riprap piled on top. This is sufficient to prevent any piping away of the soil of the embankment[6].